A Trace Element Emission Study
at
Selected Sour Gas Plant Incinerator Stacks
in
The Province of Alberta

Waterton - Shell Canada Resources Limited
Pincher Creek - Gulf Oil Canada Limited

for

Energy Resources Conservation Board
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December, 1983

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OF THE UNIVERSITY OF WINDSOR

WINDSOR, ONTARIO, CANADA - N9B 3P4

SUMMARY

A comprehensive source sampling program has been carried out at the Shell Canada Resources Limited - Waterton and Gulf Oil Canada Limited - Pincher Creek Gas Plants to establish the presence and levels of 29 metals in the gases exhausted from incinerator stacks. Modifications to the Alberta Stack Sampling Code procedures were made in order to facilitate representative sample collection, quantitative recovery and elemental analyses in the presence of other particulate matter.

Measurable levels of 18 difference elements were found at least once during twelve tests, but only iron and zinc were found consistently in all parts of the sampling train for each test. Average concentrations and emission rates of the metals found most frequently at each plant with glass lined probes are summarized below.

	Pincher Creek Volumetric Flowrate 50,000±900 acfm		Waterton Volumetric Flowrate 647,000±34,000 acfm	
Metal	Average Concentration ug/rcf	Average Emission Rate g/h	Average Concentration ug/rcf	Average Emission Rate g/h
	(Arithmetic Means with standard deviations)			
Aluminum	9.9±3.5	8.1±2.5	5.6±3.0	69±35
Copper	1.9±1.4	1.7±1.1	0.8±0.3	8.0±5.7
Iron	4.6±1.8	3.8±1.4	5.5±2.1	71±28
Titanium	9.6±1.4	8.0±1.1	11.0	186
Zinc	1.6±0.4	1.3±0.3	1.7±0.2	22±3

The nature and amounts of the elements released to the atmosphere from incinerator stacks would not appear to create a critical emission problem in the Pincher Creek area. It is recommended that computer atmospheric dispersion modelling of the emissions from both plants be carried out to more accurately assess the impact on receptors at ground level.

TABLE OF CONTENTS

Page

Summary ii

Table of Contents iii

List of Figures vii

List of Tables ix

I. BACKGROUND

A. Objectives 1

B. Scope 2

1. Preliminary Site Inspections 2

2. Preliminary Source Tests 3

3. Trace Element Emission Measurements 3

4. Trace Element Analyses 4

5. Atmospheric Dust Levels 5

II. SOURCE SAMPLING METHODOLOGY

A. Introduction 6

B. Location of Sampling Ports and Points 7

1. Port Location 7

2. Port Design 7

3. Number and Location of Sampling Points 8

C. Determination of Stack Gas Velocity and Volumetric Flow Rate 8

D. Determination of Stack Gas Composition and Molecular Weight on a Dry Basis 13

1. Gas Chromatographic Analyses 13

2. Sulphur Dioxide 13

E. Determination of Moisture Content 15

F. Determination of Particulate Emissions 15

TABLE OF CONTENTS (continued)

Page

1. Apparatus 17
    a. Pitot Assembly 17
    b. Filter and Cyclone 21
    c. Impinger Train 21
    d. Control Module 23
    e. Leak Test 23
    f. Sampling Conditions 24

G. Process Description and Sour Gas Plant Operating Conditions 24
1. Waterton Gas Plant (Shell Canada Resources Limited) 25
2. Pincher Creek Gas Plant (Gulf Oil Canada Limited) 29

III. SAMPLE RECOVERY

A. Introduction 33

B. Nozzle - Probe 33
1. Nozzle 33
2. Probe 35
3. Nozzle - Probe Blanks 35

C. Filter 36
1. Filter Removal 36
2. Cyclone - Bypass and Filter Front End 36

D. Impinger Train 36
1. Moisture Determination 36
2. Impingers 1, 2 and 3 at Ice-Water Bath Temperature 37
3. Blank - Impingers 1, 2 and 3 37
4. Impingers 4 and 5 at Dry Ice-Acetone Bath Temperature 37

TABLE OF CONTENTS (continued)

Page

5. Blank-Impingers 4 and 5 37

6. Connecting Glassware 37

IV. ANALYTICAL PROCEDURES

A. Development 39

1. Pre-Test Program 39

2. Preliminary Field Testing 41

B. Plant Tests 42

C. Atomic Absorption Spectrometry 42

V. RESULTS

A. Development 52

1. Pre-Test Program 52

2. Preliminary Field Testing 52

B. Plant Tests 56

VI. DISCUSSION OF RESULTS

A. Shell-Waterton 64

1. Stainless Steel Liner 64

2. Glass Liner 65

B. Gulf-Pincher Creek 65

C. Total Particulate Matter Emissions 65

D. Comparisons of Plant Operations 66

E. Random Error Analysis 67

VII. CONCLUSIONS AND RECOMMENDATIONS 68

REFERENCES 69

APPENDIX I. Gas Chromatograph Calibration
Gas Analysis and
Technical Data on Ultra-Pure
QM-A Quartz Filters 72

TABLE OF CONTENTS (continued)

Page

APPENDIX II. Preparation of Demineralized Water and Actual Lot Analysis (218042) for Baker Instra-Analyzed Nitric Acid 77

APPENDIX III. Inductively Coupled Argon Plasma Spectrometer Specifications 80

APPENDIX IV. Field Sampling Data and Elemental Emission Rates 82

APPENDIX V. Plant Operating Data 130

APPENDIX VI. Procedure for Estimating Maximum Possible Emission Rates of All Elements of Interest 133

LIST OF FIGURES

Page

2.1 Detail of Incinerator Stack at Sampling Platform Elevation 9

2.2 Modifications to Existing Sampling Ports 10

2.3 Cross-section of Circular Stack Divided into Equal Areas with Traverse Points Located at Center of each Area 11

2.4 Traverse Point Multiples to Determine Minimum Number of Traverse Points Required When $A < 2$ or $B < 8$ 11

2.5 Relative Position of RTD/Pitot Tube/Sampling Nozzle Used in Calibration and Sampling 14

2.6 Basic Sampling Train for Particulate Matter 16

2.7 Sampling Train for Trace Metals 18

2.8 Plan and Cross-Sectional Views of Air Cooled Probe 19

2.9 Shell Canada Resources Limited Waterton Gas Plant at Pincher Creek, Alberta. 25

2.10 Simplified Flow Schematic for Waterton Gas Plant 26

2.11 Waterton Gas Plant Block Diagram 27

2.12 Detailed Flow Diagram for Pincher Creek Gas Plant 30

2.13 Simplified Flow Schematic for Gulf Oil Canada Limited Pincher Creek Gas Plant 31

3.1 Sample Recovery Procedure 34

4.1 Treatment of Filters From Final Tests 43

4.2 Treatment of Solutions From Final Tests 44

4.3 Preparation of Blanks for Filters and Solution Analyses 45

4.4 Preparation of Solutions for Component Recoveries From Filters 48

4.5 Preparation of Solutions for Component Recoveries From Solutions 49

LIST OF FIGURES (CONTINUED)

Page

4.6 Treatment of $HN0_3$ and HCl Solutions for Atomic Absorption Spectrometry 51

5.1 Maximum Emission Rates of Metals Whose Presence Was "Detected" in Shell-Waterton Incinerator Stack Gases Using a Stainless Steel Liner 59

5.2 Maximum Emission Rates of Metals Whose Presence Was "Detected" in Shell-Waterton Incinerator Stack Gases Using a Borosilicate Glass Liner 60

5.3 Maximum Emission Rates of Metals Whose Presence Was "Detected" in Gulf-Pincher Creek Incinerator Stack Gases Using a Borosilicate Glass Liner 61

II.1 Preparation of Demineralized Water by Energy Resources Conservation Board Laboratory, Edmonton, Alberta 78

VI.1 Maximum Possible Emission Rates of All Elements in Shell-Waterton Incinerator Stack Gases (Stainless Steel Liner) 146

VI.2 Maximum Possible Emission Rates of All Elements in Shell-Waterton Incinerator Stack Gases (Borosilicate Glass Liner) 147

VI.3 Maximum Possible Emission Rates of All Elements in Gulf-Pincher Creek Incinerator Stack Gases (Borosilicate Glass Liner) 148

VI.4 Effect of Preconcentration on Reported Emission Rates 151

LIST OF TABLES

		Page
1.1	Trace Metals of Interest	4
2.1	Sampling Port Characteristics	7
2.2	Minimum Number of Traverse Points for Sampling Stacks	11
2.3	Location of Traverse Points in Circular Stacks	12
2.4	Approximate Composition and Physical Properties of Borosilicate Glass Probe	20
2.5	Method 4 Impinger Train	22
2.6	Trace Element Impinger Train	22
2.7	Summary of Test Conditions	24
2.8	Process Information Obtained at Each Plant on an Hourly Basis for Each Test Run	24
4.1	Summary of Analytical Parameters for Atomic Absorption Analysis	40
4.2	Amounts of Standards Added to Filters for Recoveries Using 1000 ppm Standards	46
4.3	Amounts of Standards Added to Solutions for Recoveries Using 1000 ppm Standards	47
5.1	Summary of ICAP Analyses of Baker Instra-Analyzed Nitric Acid Blanks	53
5.2	Comparison of Filter Qualities on the Basis of Inductively Coupled Argon Plasma Spectrometry	54
5.3	Summary of Metal Levels in Probe, Filter and Impinger Washes as Determined by Inductively Coupled Argon Plasma Analyses	55
5.4	Laboraory Recoveries of Spiked Filters	57
5.5	Laboratory Recoveries of Spiked Liquids	58
5.6	Summary of Emission Rates of Elements Whose Presence Was Established at Shell-Waterton and Gulf-Pincher Creek Gas Plants Using Stainless Steel or Borosilicate Glass Lined Probes	62

LIST OF TABLES (CONTINUED)

Page

6.1 Comparison of Elemental Emission Rates Based on Sample Recovery From Stainless Steel and Borosilicate Glass Lined Probes at Shell-Waterton Gas Plant 64

6.2 Comparison of Average Concentrations and Emission Rates of Metals Found in the Pincher Creek and Waterton Gas Plant Incinerator Stacks 67

II.1 Actual Lot Analysis (218042) for Baker Instra-Analyzed Nitric Acid 79

IV. 1 to IV.47 Field Sampling Data and Elemental Emission Rates 83 to 129

V.1 Plant Operating Data at Shell Canada Resources, Waterton Gas Plant 131

V.2 Plant Operating Data at Pincher Creek-Gulf Oil Canada Limited 132

VI.1 to VI.8 Summary of Incinerator Stack Source Sampling Tests - Shell Waterton Plant 135 to 142

VI.9 to VI.11 Summary of Incinerator Stack Source Sampling Tests - Gulf-Pincher Creek 143 to 145

VI.12 Summary of Arsenic Determinations at Shell-Waterton Gas Plant (Borosilicate Glass Liner) 149

I. BACKGROUND

This study was initiated in response to a request by Dr. H.F. Thimm, Senior Environmental and Technical Advisor, Environment Protection Department, Energy Resources Conservation Board (ERCB) on June 15, 1982. The objectives and scope of this work were reviewed and defined in group discussion and telephone conversations by Dr. H.F. Thimm, Dr. A.W. Gnyp, P.Eng., and Dr. C.C. St. Pierre, P.Eng., of the Department of Chemical Engineering, University of Windsor.

In order to formulate a work plan, representative stack gas analyses, velocity measurements and sulphur dioxide emissions data from the following sour gas plants were employed:

a) Shell - Waterton(1)

b) Esso - Quirk Creek(2)

c) Shell - Jumping Pound(3)

d) Gulf - Strachan(4)

e) Canterra - Ram River(5)

Preliminary trace metal emission studies for the Shell - Waterton site(6–9) and three additional sulphur plant incinerator stacks (Shell-Innisfail; Hudson's Bay-Lone Pine Creek; Petrofina-Wildcat Hills(10)) were reviewed to assist in development of sample recovery and analysis procedures.

A formal proposal submitted on June 29, 1982 was accepted by the Energy Resources Conservation Board on July 19, 1982.

A. OBJECTIVES

The objectives of this investigation were to:

a) Conduct a trace element emission study at incinerator stacks of the sour gas plants located at

Shell - Waterton

Esso - Quirk Creek

Shell - Jumping Pound

Gulf - Strachan

Canterra - Ram River

Gulf - Pincher Creek*

b) Measure atmospheric dust levels using hi-vol samplers at one city and one rural location to establish background elemental concentrations

*Plant site added September 29, 1982.

c) Attend open houses in the Pincher Creek and Calgary areas during the month of October 1982.

d) Prepare a detailed written description of the proposed sampling and analytical methodology for review by a panel of chemists and chemical engineers chosen by the ERCB.

e) Present a seminar at a scientific meeting in the Calgary area, with invitations to interested scientists throughout Alberta, when arranged by the Board during the month of November 1982.

B. SCOPE

As a result of the initial meeting at the University of Windsor with Dr. H. Thimm on June 25, 1982, a review of the sulphur emission studies and preliminary heavy metal results, extensive literature research and personal discussions with members of Canadian and U.S. regulatory agencies, the testing program was divided into five distinct parts.

1. Preliminary Site Inspections

Preliminary site inspections were conducted at all designated sour gas sulphur plant incinerator stacks (except Gulf-Pincher Creek) by D.S. Smith,P.Eng., H.F. Thimm, Ph.D., and R.J. Farion, Senior Gas Plant Inspector or S. Slyman, Assistant Area Supervisor, ERCB during the week of July 12-16, 1982, to obtain the pre-test information specified by the Alberta Stack Sampling Code(11). The Gulf-Pincher Creek plant was inspected on September 30, 1982 by D. Smith and R. Farion. On the basis of these five initial visits, it became evident that:

a) a 17-ft. air cooled sampling probe was required for three stacks with diameters exceeding fifteen feet,

b) special port modifications were necessary to facilitate movement and support of the 17-ft. probe,

c) the location of refractory lined sampling ports were fixed but they could be adapted structurally to accommodate the required air cooled sampling probes,

d) the stack sampling personnel would be restricted by the limited platform extensions in place, consequently, innovative probe and train support systems had to be designed.

Following the field inspections and review of the sampling strategy, necessary modifications to sampling ports, monorail supports, guard rails, power and compressed air requirements were defined.

Engineering drawings and specifications were prepared and forwarded to the plant liaison at each site for implementation by plant operators in order to allow sampling to begin by August 19, 1982.

2. Preliminary Source Tests

Preliminary source testing was carried out at each incinerator stack to obtain:

a) the gas stream composition in terms of water vapour, carbon monoxide, carbon dioxide, nitrogen, argon, oxygen and sulphur dioxide

b) an estimate of total particulate concentration in the exhaust stream using an approved stack sampling train

c) the velocity distribution and total volumetric flowrate at the sampling port elevation

d) an estimate of the total particulate emission rate

e) elemental analyses of the samples recovered from four different locations in the sampling train at two different plants

These preliminary tests were necessary in order to facilitate isokinetic sampling of all stacks in accordance with the Alberta Environment Source Sampling Code(11). Two initial elemental analyses were conducted in order to determine the limits of detection for each element and to finalize the analytical methods.

3. Trace Element Emission Measurements

A minimum of three complete particulate emission tests were conducted at each of the five designated sour gas sulphur plant incinerator stacks using sampling procedures and equipment consistent with Alberta Environment requirements(11) or as mutually agreed to with Dr. H. Thimm, Energy Resources Conservation Board.

Sample recovery was done in four distinct parts involving:

a) nozzle-probe washings

b) filter catch

c) impinger assembly catch

d) cold trap catch

in order to provide an approximation of the particle size distribution and separation of gas phase versus solid phase trace elements in terms of the location of sample deposition in the train.

Each complete test provided:

a) gas stream composition in terms of water vapour, carbon monoxide, carbon dioxide, nitrogen, argon, oxygen and sulphur dioxide

b) the local velocity distribution and total volumetric flowrate

c) suitable samples for elemental analyses

d) the individual trace element concentrations

e) the individual trace element emission rates

4. Trace Element Analyses

For every particulate emission test the samples collected at each of the four distinct parts of the train was analyzed for the trace elements listed in Table 1.1.

Element (Symbol)	Element (Symbol)
Lithium (Li)	Selenium (Se)
Thallium (Tl)	Molybdenum (Mo)
Chromium (Cr)	Cadmium (Cd)
Titanium (Ti)	Antimony (Sb)
Vanadium (V)	Mercury (Hg)
Manganese (Mn)	Lead (Pb)
Iron (Fe)	Strontium (Sr)
Cobalt (Co)	Beryllium (Be)
Nickel (Ni)	Boron (B)
Copper (Cu)	Indium (In)
Zinc (Zn)	Tellurium (Te)
Germanium (Ge)	Silver (Ag)
Gallium (Ga)	Aluminum (Al)
Arsenic (As)	Scandium (Sc)
	Tin (Sn)

Table 1.1. Trace Metals of Interest

These elements were selected after a comprehensive review of open literature and discussions with personnel from Canadian and American regulatory agencies as well as ERCB representatives.

For common metals (exclusive of hexavalent chromium, arsenic, selenium, mercury and vanadium) the samples were ultimately disssolved in dilute hydrochloric or nitric acid and the resulting solutions were analyzed by an atomic absorption spectrophotometer using a hollow cathode lamp for the specific metal. Two recoveries and two laboratory blanks were analyzed with each series of samples.

Samples of arsenic, selenium and vanadium were analyzed using a furnace (electrothermal) technique which yields greater sensitivity and lower limits of detection (12) than direct flame atomization. Mercury was determined using the cold vapour method in which mercury vapour was generated with 20% stannous chloride for purging into the atomic absorption detection cell.

Split samples from the Ram River-Canterra Gas Plant (13) were analyzed for two data sets by a second independent laboratory for intralaboratory comparisons.

5. Atmospheric Dust Levels

High volume dust samplers were used to establish atmospheric dust levels at two mutually agreed upon locations representing urban and rural sites where trace element concentrations were projected to be unaffected by sour gas plant emissions.

Twenty-four hour samples were collected at each site according to EPA Reference Methods(14) for elemental analysis of the filter catches.

II. SOURCE SAMPLING METHODOLOGY

A. INTRODUCTION

A literature search and personal discussions with Canadian and United States regulatory personnel indicated that an approved source sampling reference method(s) did not exist for measuring trace elements in stationary source emission streams. Several publications(12, 14-18) and personal contacts(19-21) indicated that many of the potentially hazardous metal species present at trace levels in emission streams are largely of submicron particle size (0.1-1.0 microns in diameter). This size corresponds to the lower collection efficiency of stack sampling train filters and pollution control devices.

The large stack diameters (up to 20 feet) and elevated stack temperatures (800-1,200°F) also presented significant probe design challenges. The most critical problem was successful incorporation of a glass liner which would insure minimal sample contamination and facilitate sample recovery.

In order to develop suitable sampling and analytical methodologies for trace levels of metals the following objectives had to be met:

a) collection of a representative sample

b) minimization of sample loss in the train and contamination by sampling train components

c) quantitative recovery of the sample from all parts of the train

d) development of suitable sample pretreatment procedures to achieve solubilization, concentration and negligible interference

e) development of suitable analytical procedures to carry out instrumental analysis of trace metals in the presence of unknown amounts of other particulate matter.

Collection of a representative sample and minimization of contamination are discussed here. Every effort was made to follow the Alberta Environment Stack Sampling Code Reference Methods (AERM)(11). Due to the size and complexity of the sampling train, the need for meticulous sample recovery procedures, and restrictive platform dimensions, three samplers were initially used at the incinerator stacks.

The source testing supervisor, Mr. D. Smith, was present for all tests. He is a registered Professional Engineer in the Province of Ontario with a Master of Applied Science degree in Chemical Engineering and ten years relevant experience. All team members had successfully completed a suitable source sampling course and possessed relevant engineering backgrounds (including Ph.D. and M.ASc. degrees).

B. LOCATION OF SAMPLING PORTS AND POINTS

1. Port Location

The sampling ports and platforms were already installed at all sour gas plant incinerator stacks. Their locations provided the vertical straight lengths downstream and upstream from the nearest flow disturbances listed in Table 2.1.

Plant Location	Stack Diameter (ft)	Number of Ports	Distance to Nearest Disturbance Downstream	Distance to Nearest Disturbance Upstream
			Stack Diameters	
Gulf-Strachan	15.7	4	8	2
Canterra-Ram River	20.1	4	4.6	2
Shell-Jumping Pound	5.5	2	8	2
Shell-Waterton	15.1	2	6.2	2
Gulf-Pincher Creek	4.3	2	8	2

Table 2.1 Sampling Port Characteristics

The preferred sampling site according to the AERM No. 1[(11)] is at least eight stack diameters downstream and a minimum of two diameters upstream from the nearest flow disturbance. When these conditions were not satisfied, the number of sampling points was increased above the minimum requirements specified by AERM.

2. Port Design

The sampling ports and/or platforms at all plants required a variety of minor modifications in order to support the train monorail, eliminate obstructions in the sampling train travel path and to standardize to 4-inch diameter Schedule 40 male - threaded pipe nipples. Preliminary field inspections were conducted at all sites to allow preparation of engineering drawings and specifications for submission to plant operators who arranged the necessary changes.

Special port adaptations were necessary to facilitate movement and support of the 17 foot sampling probe required for the stacks with diameters exceeding 15 feet . This probe length was necessary, even though four ports were installed, since these large diameter stacks were designed with inner steel linings and outer concrete shells having annuli ranging from 7 1/2 to 11 feet as illustrated in Figure 2.1. Probe alignment and movement were facilitated by construction and installation of new 4-inch Sch 40 pipe sampling ports of the required length fitted with two sets of rollers as illustrated in Figure 2.2. The 4-in. ports were fitted with end caps to seal the opening when the ports were not in use.

3. Number and Location of Sampling Points

The number and location of traverse points were determined according to AERM No. 1(11) in order to provide the required number of equal sampling areas, as illustrated in Figure 2.3. When the upstream distance to the nearest disturbance was greater than 8 diameters Table 2.2 was used. For stacks with less than 8 diameter distances, Figure 2.4 was employed to increase the required number of sampling points. Table 2.3 facilitated location of the points on a diameter for up to 24 points per traverse. The following equation:

$$R = 100\left(0.5 - \sqrt{\frac{2n-1}{4N}}\right)$$

where: $n = \frac{N}{2} + (1-h)$

R = percentage of stack diameter from port
h = sampling point number from port
N = number of sampling points per traverse

was used to extrapolate Table 2.3 when 26 or more points were required on a traverse.

C. DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE

Method 1 (AERM)(11) was followed during measurement of local stack velocities needed to calculate the total volumetric flowrate through the incinerator stack at the sampling elevation.

All velocity measurements were made using an S-type Pitot tube. A calibrated sheathed resistance thermometer (RTD), attached to the probe assembly allowed simultaneous temperature and velocity pressure measurements. The Pitot tube coefficients were obtained

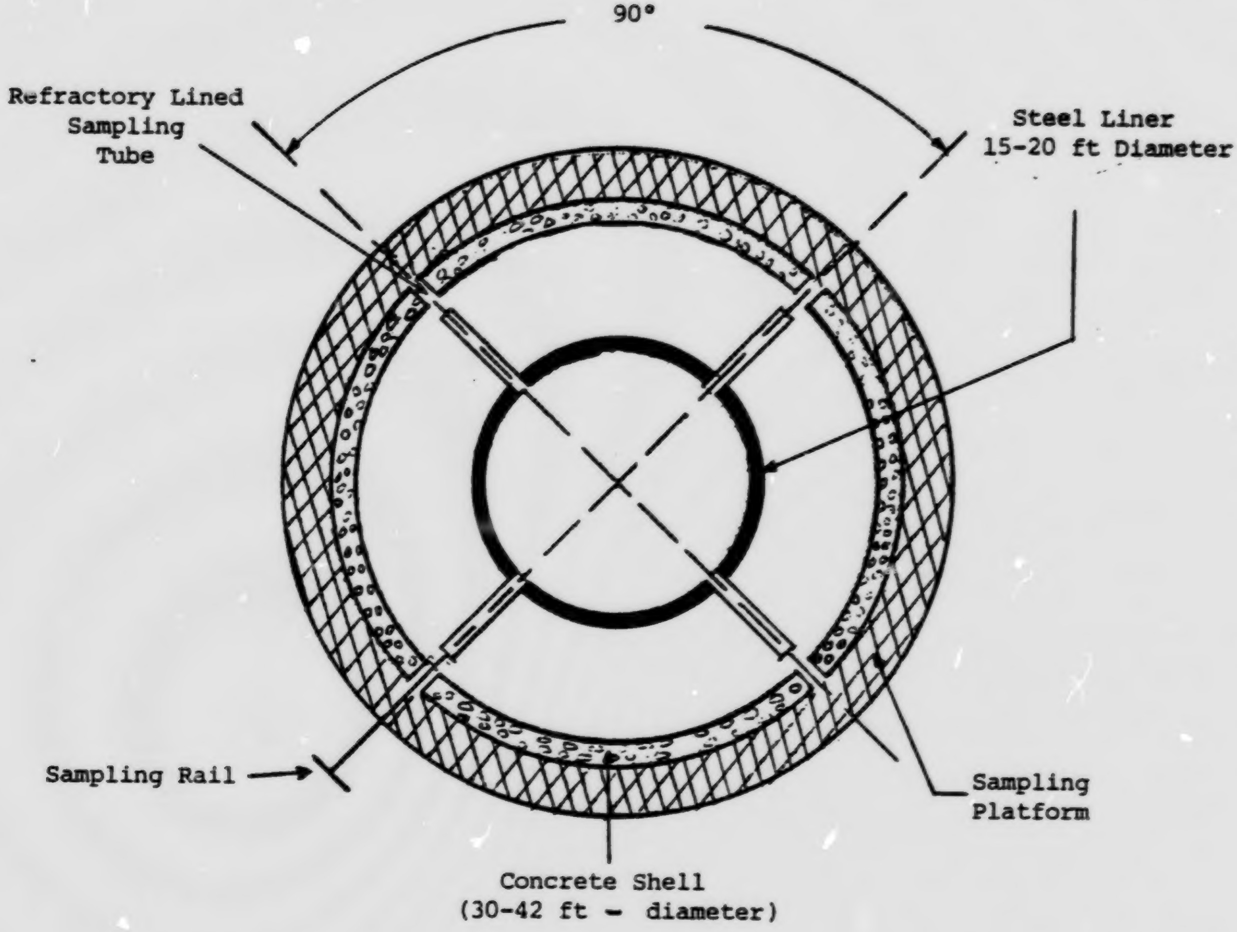

90°
Refractory Lined Sampling Tube
Steel Liner 15-20 ft Diameter
Sampling Rail
Sampling Platform
Concrete Shell (30-42 ft - diameter)

Figure 2.1 Detail of Incinerator Stack at Sampling Platform Elevation

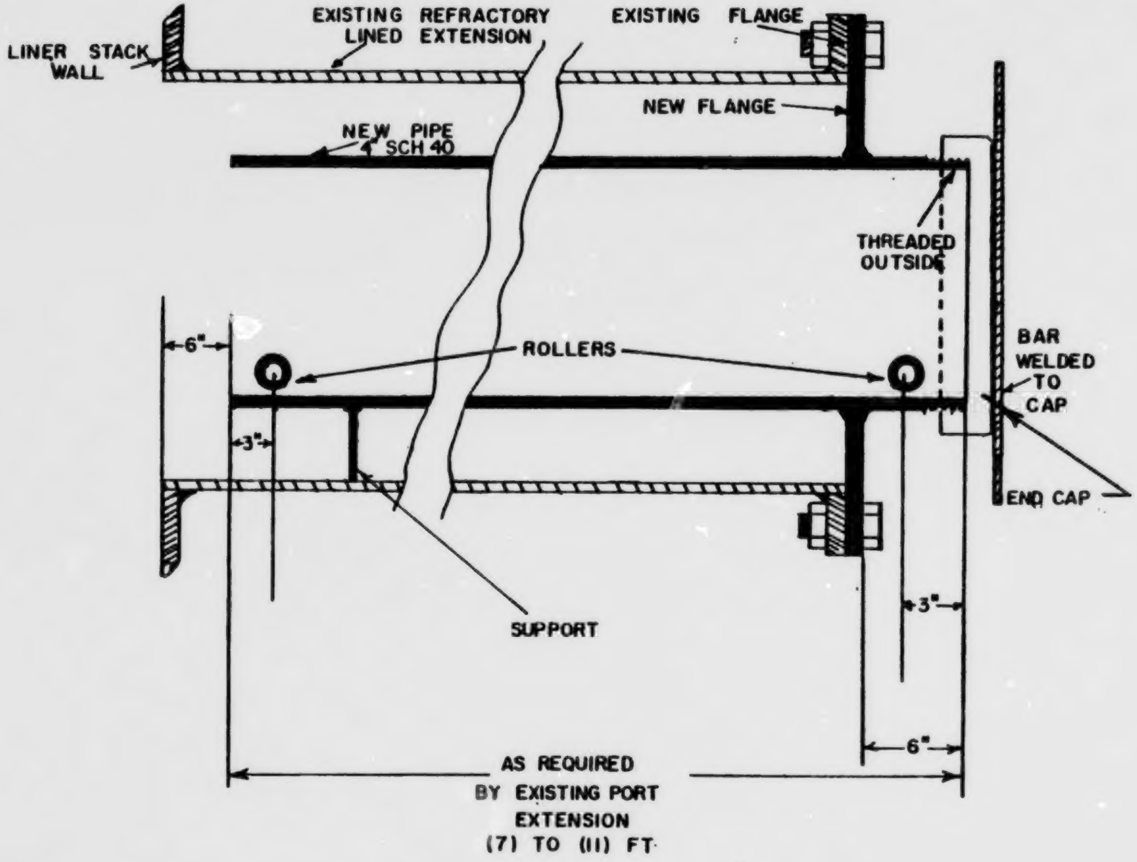

EXISTING REFRACTORY LINED EXTENSION
EXISTING FLANGE
LINER STACK WALL
NEW FLANGE
NEW PIPE 4" SCH 40
THREADED OUTSIDE
BAR WELDED TO CAP
ROLLERS
END CAP
6"
3"
SUPPORT
3"
6"
AS REQUIRED BY EXISTING PORT EXTENSION (7) TO (11) FT

Figure 2.2 Modifications to Existing Sampling Ports

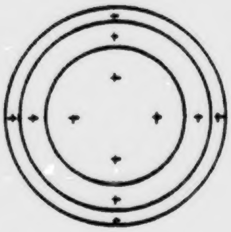


Figure 2.3

Cross-Section of Circular Stack Divided into Equal Areas with Traverse Points Located at Center of Each Area

Duct Diameter, Ft.	Minimum Number of Sampling Points Required per Traverse
*Less than 1	2
1< I.D.≤ 2	4
2<I.D.≤ 4	8
4<I.D.≤ 8	10
8<I.D.≤ 16	16
Greater than 16	Refer to Alberta Environment for approval before testing.

I.D. = Inside diameter of stack

Table 2.2
Minimum Number of Traverse Points for Sampling Stacks (11)

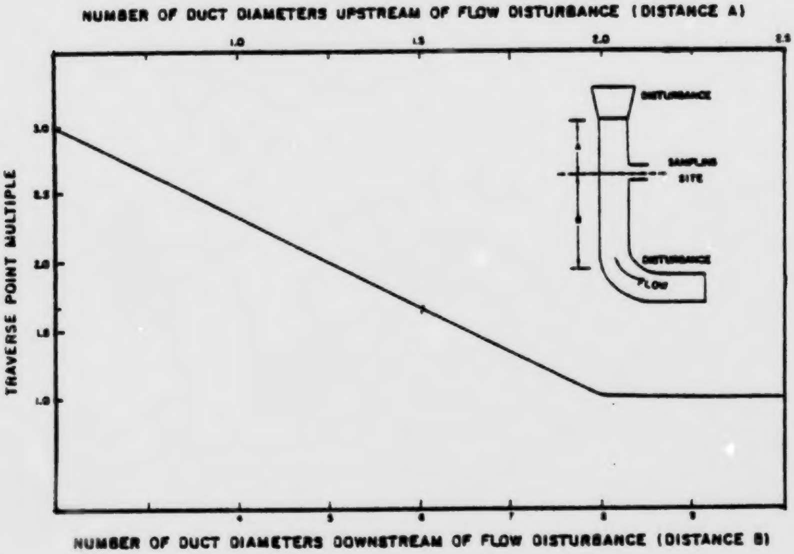


Figure 2.4
Traverse Point Multiples to Determine Minimum Number of Traverse Points Required When A < 2 or B < 8 (11)

Percent of Stack Diameter from Inside Wall to Traverse Point												
Traverse Point Number On A Diameter	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.3	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.7	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.5	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.5	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.3	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.5	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.5	36.6	28.3	23.6	20.4	18.0	16.1
8				96.7	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.1	23.0
10					97.5	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.9	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

Table 2.3 Location of Traverse Points in Circular Stacks

for all the RTD/Pitot tube/sampling nozzle combinations, as illustrated in Figure 2.5, using the wind tunnel located in the University of Windsor Department of Mechanical Engineering. The procedure described in Appendix 2A, Method 2, of the Ontario Source Testing Code(22) was followed.

Since the 17-ft probe could not fit into the wind tunnel an exact replica of shorter overall length employing the actual component parts, was fabricated to allow proper calibration. The 8-ft effective length probe was calibrated exactly as used in the field.

An inclined manometer with a readability of 0.1 inches of water was employed to measure the velocity pressure. Barometric pressures were obtained from the plant laboratory in Waterton for each sampling period.

The absence of cyclonic and/or flow reversals was confirmed at all sampling locations.

D. DETERMINATION OF STACK GAS COMPOSITION AND MOLECULAR WEIGHT ON A DRY BASIS

The molecular weight of the exhaust gas stream on a dry basis required for use in Method 5 (AERM)(11) was calculated employing on-site gas chromatographic analyses.

1. Gas Chromatographic Analyses

Integrated ten minute samples were collected by drawing air with a Neptune Model 4K vacuum pump into an 18 litre Tedlar sampling bag. The gas composition in terms of carbon dioxide, carbon monoxide, oxygen, and nitrogen was determined with a Carle Model AGC III gas chromatograph equipped with 1/4-inch by 2-feet long Porapak Q (100-200 mesh) and 1/4-inch by 6-foot long molecular sieve 13X columns. One side of the thermal conductivity detector was located between the Porapak Q and molecular sieve columns while the other side was at the outlet of the molecular sieve column. The instrument, operated isothermally at 55°C with a helium flowrate of 40 cm^3/min, was calibrated with a known mixture of nitrogen, oxygen, carbon dioxide, and carbon monoxide. The standard gas was prepared by Western Research and Development. Its composition was checked by an independent analysis carried out by DB Robinson & Associates, Ltd. of Edmonton, Alberta. Appendix I documents the results of the calibration of the standard gas. Analysis was performed on 1000 microlitre injections immediately following each test run.

2. Sulphur Dioxide

Sulphur dioxide concentrations in the exhaust stream were obtained by following Method 5 (AERM)(11) for sulphur dioxide emission measurements only. A constant sampling rate of approximately 0.1 cubic feet per minute was employed to

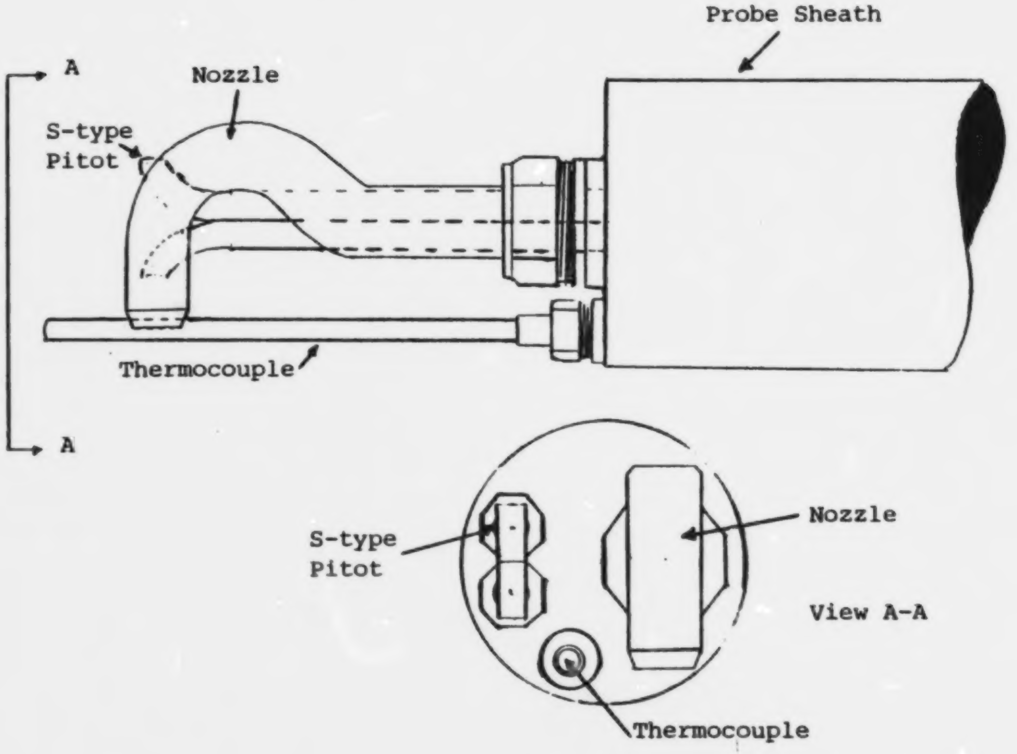

Probe Sheath
A
Nozzle
S-type
Pitot
Thermocouple
A
S-type
Pitot
Nozzle
View A-A
Thermocouple

Figure 2.5 Relative Position of RTD/Pitot Tube/Sampling Nozzle Used in Calibration and Sampling

provide total sample volumes of 2 to 6 cubic feet. After sampling, the two midget impingers containing 3% hydrogen peroxide were transferred, along with impinger rinses, to 25 ml glass sample vials fitted with Teflon caps.

In the laboratory, analysis was accomplished by the technique outlined in Method S308 of the NIOSH Manual of Analytical Methods(23), in which isopropyl alcohol is added to the samples. The pH of each sample is adjusted with perchloric acid, and the sulfate content of each sample determined by titration with barium perchlorate solution using Thorin indicator. Results of analyses (calculated as SO_2), which include any necessary correction for blank determinations run in parallel with the analysis, were used in conjunction with field sampling data to calculate the reported concentrations of sulphur dioxide. This analytical method is consistent with Method 5 (AERM)(11) requirements.

E. DETERMINATION OF MOISTURE CONTENT

The moisture content of a stack gas was obtained employing the condensation method of Method 3 (AERM).(11) This determination was made simultaneously with the particulate (trace element) sampling programme.

The mass of condensate collected in the impingers and dessicant (Drierite) was determined by weighing all containers before and after sampling to the nearest 0.1 gm.

This water mass was converted to an equivalent gaseous volume. The volume fraction of moisture in the stack gas is calculated using the corresponding total gas sample volume at reference conditions (530°R, 29.92 inches Hg).

F. DETERMINATION OF PARTICULATE EMISSIONS

The measurement of particulate emission rates according to Method 4 (AERM)(11) requires isokinetic sampling and particulate separation from the extracted gas stream using dry filter media and wet scrubbing in a series of impingers, using the basic sampling train illustrated in Figure 2.6. In order to extract and transport the samples from the stack to the collection media with minimal contamination, a glass liner was used. For sour gas incinerator stacks, having gas stream temperatures in the 800 to 1,200°F range, two custom gas cooled probes were designed and constructed. The use of acid solutions in the impingers and the addition of two impingers kept at the dry ice-acetone temperature, helped to promote submicron particulate removal.

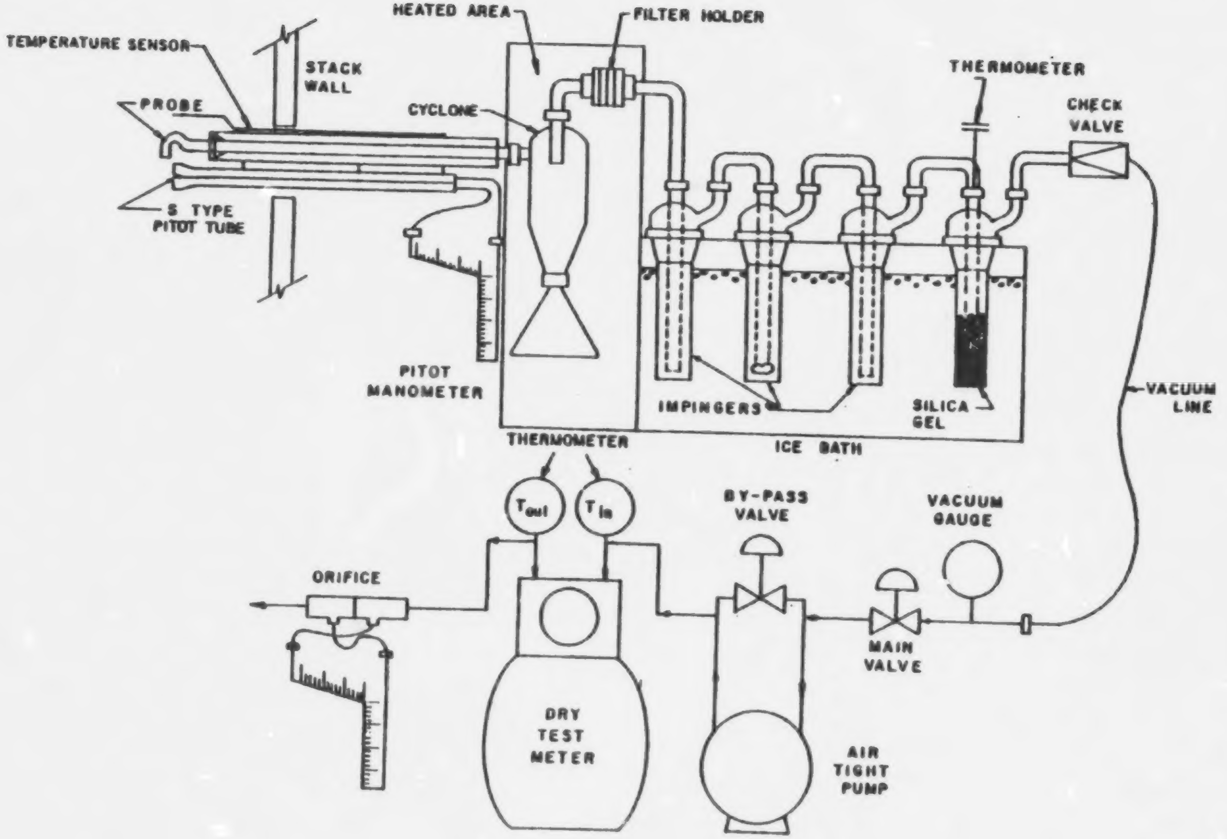

HEATED AREA
FILTER HOLDER
TEMPERATURE SENSOR
STACK WALL
PROBE
CYCLONE
THERMOMETER
CHECK VALVE
S TYPE PITOT TUBE
PITOT MANOMETER
IMPINGERS
SILICA GEL
VACUUM LINE
ICE BATH
THERMOMETER
T_{out}
T_{in}
BY-PASS VALVE
VACUUM GAUGE
ORIFICE
MAIN VALVE
DRY TEST METER
AIR TIGHT PUMP

Figure 2.6 Basic Sampling Train for Particulate Matter

The recommended isokinetic sampling procedures of AERM No. 4 were followed for all particulate emission tests. Preliminary tests were not always isokinetic. The leak check for the 17 foot probe had to be modified since the recommended procedure could not be performed on the sampling platform due to space limitations. Sample recovery and analyses, which were much more rigorous than those required for the usual particulate matter sampling tests, are described in detail in the next two sections.

All substantial modifications to the sampling apparatus and procedures of Method 4 are described in detail here. The choice of components and absorbing solutions represents an optimum in terms of a single procedure for sampling and pretreatment of all the elements of concern, although, such pretreatment might not be best on an individual element basis.

1. Apparatus

The sampling train employed is schematically illustrated in Figure 2.7.

a) Pitot Assembly

Two custom air cooled probes were fabricated in the University of Windsor, Chemical Engineering Workshop, by Mr. G. Ryan. Figure 2.8 details the probes in cross-section and plan. Sheathed, remote temperature devices (RTD) capable of withstanding the high gas stream temperatures and compatible with the existing electronics of the temperature readout units were incorporated into the probe assemblies.

Sampling nozzles of the button-hook type were constructed of 316 stainless steel. They were the only components of the train not made of glass that contacted the extracted gas sample stream.

Borosilicate glass was selected for the 5/8-in. glass probe liners since it could withstand more mechanical and thermal shock than Vycor. In addition, borosilicate glass had been successfully employed in trace metal sampling programmes previously(13).

The approximate composition of the borosilicate glass probe is provided in Table 2.4. Tests have shown(24) minimal trace element leaching by acidic solutions similar to those employed during this study for sample recovery.

A 5/8-in. diameter 316 stainless steel liner was also constructed to provide a back-up capability if the gas-cooled probe could not provide sufficient thermal shock protection to the glass liner.

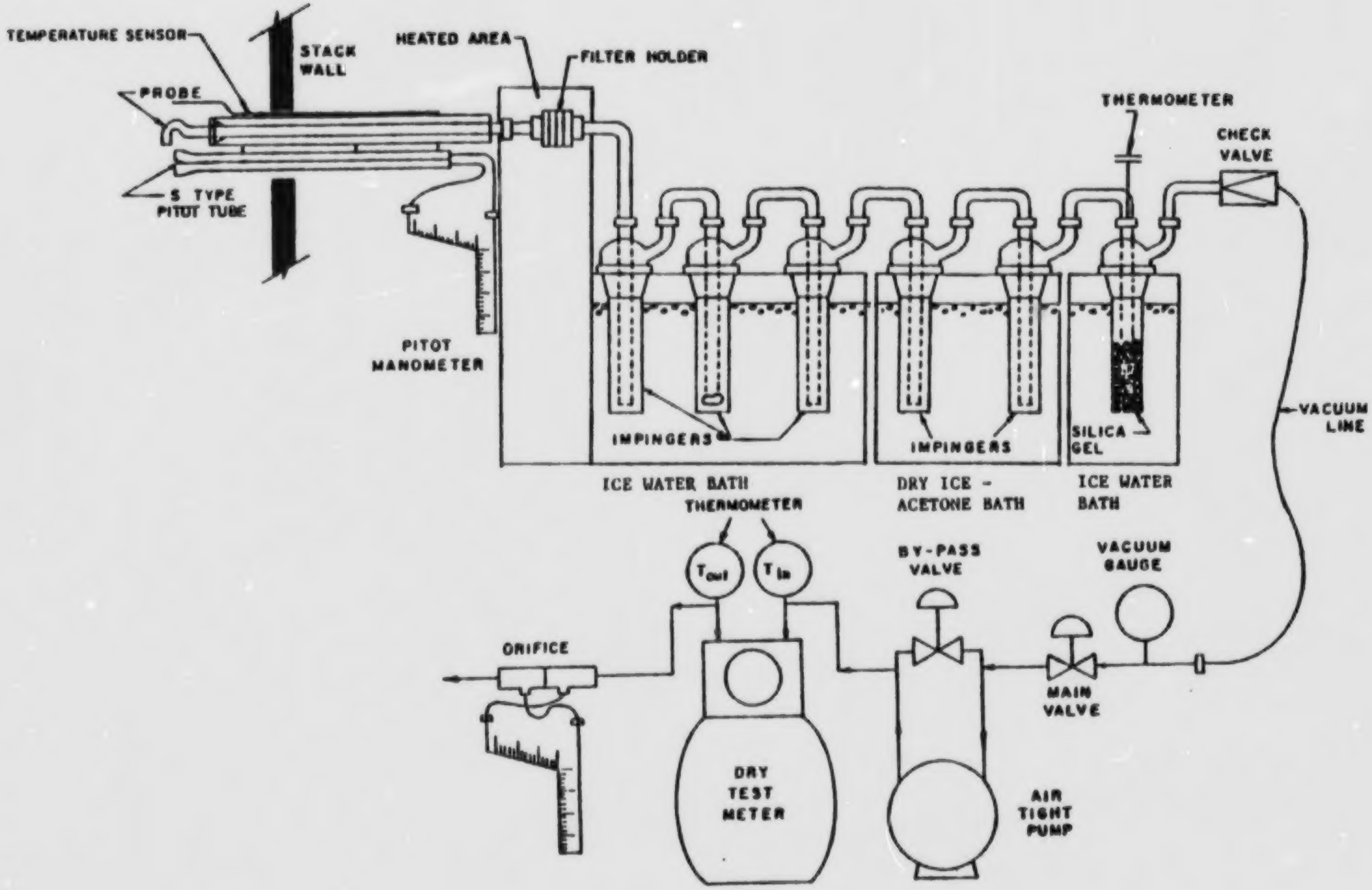

TEMPERATURE SENSOR
PROBE
S TYPE PITOT TUBE
STACK WALL
HEATED AREA
FILTER HOLDER
PITOT MANOMETER
THERMOMETER
CHECK VALVE
IMPINGERS
IMPINGERS
SILICA GEL
VACUUM LINE
ICE WATER BATH
DRY ICE - ACETONE BATH
ICE WATER BATH
THERMOMETER
T_{out}
T_{in}
BY-PASS VALVE
VACUUM GAUGE
ORIFICE
MAIN VALVE
DRY TEST METER
AIR TIGHT PUMP

Figure 2.7 Sampling Train for Trace Metals

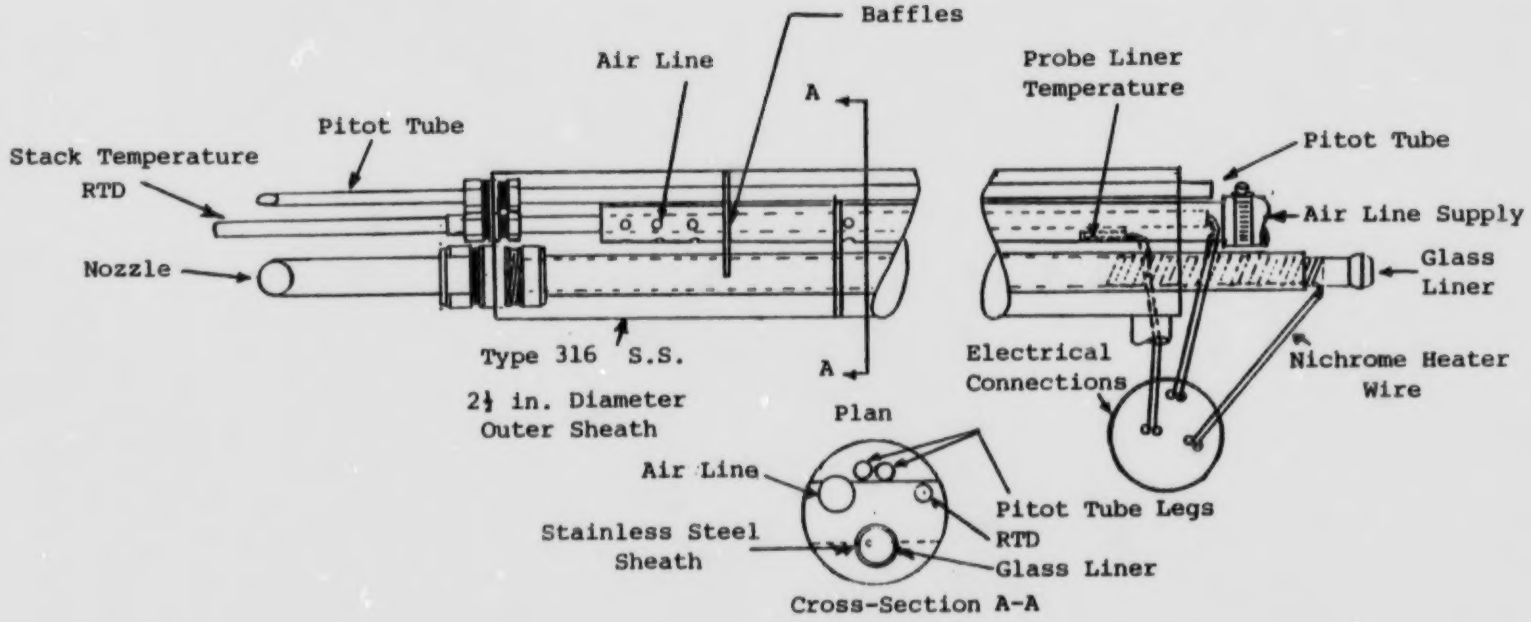

Baffles
Air Line
A
Probe Liner
Temperature
Pitot Tube
Stack Temperature
RTD
Pitot Tube
Air Line Supply
Nozzle
Glass
Liner
Type 316 S.S.
A
Electrical
Connections
Nichrome Heater
Wire
2½ in. Diameter
Outer Sheath
Plan
Air Line
Pitot Tube Legs
Stainless Steel
Sheath
RTD
Glass Liner
Cross-Section A-A

Figure 2.8 Plan and Cross-Sectional Views of Air Cooled Probe

Composition (%) by weight

SiO_2	B_2O_3	Al_2O_3	Na_2O	K_2O
80.5	12.9	2.2	3.8	0.4

Physical Properties

Softening Temp. ^{o}F	Annealing Temp. ^{o}F	Strain Temp. ^{o}F	Maximum Temp. ^{o}F	Specific Gravity	Coefficient of Linear Expansion $F^{-1} x 10^{7}$
1508	1027	950	932-1022	2.23	18

Table 2.4. Approximate Composition and Physical Properties of Borosilicate Glass Probe.(25)

The annular flow area between the outer stainless steel sheath and inner protective tube containing the glass liner was baffled to enhance heat removal. The back half of the probe was wound with Nichrome heating wire to ensure that no condensation occurred in the probe length exposed to the ambient atmosphere. Cooling air was provided by a self-contained Fuji Ring Compressor Model VFC 302P-5T centrifugal blower with a capacity of 30 cubic feet per minute or plant compressed air supplied at the sampling platform level. The cooling air flow rate was adjusted to achieve the necessary balance between heat removal consistent with glass probe liner protection and excessive cooling leading to possible condensation.

All Pitot-RTD-nozzle combinations were calibrated (for all possible sampling nozzle diameters) prior to and following field use to derive the S-type pitot tube coefficients corresponding to actual use in the sampling programme(22).

b) Filter and Cyclone

A cyclone was not used as a sampling train component since previous studies indicated that particulate sizes were not sufficiently large to be captured by the normal cyclone design employed in stack sampling trains. The glass probe liner was connected directly to the 12.5 cm diameter filter holder with a cyclone by-pass constructed of Pyrex glass.

Several filter media have collection efficiencies greater than 99% (for 0.3 micron dioctyl phthalate particles) for face velocities of 12 to 125 cm/s. The conventional glass fibre filter material manufactured by Reeve Angel (Whatman, Inc.) Type 934 AH and the Ultra-Pure QM-A quartz micro fibre filters, supplied by Whatman were selected for blank metal checks (See Appendix I for technical data). A special run of the 12.5 cm diameter QM-A-quartz micro fibre filters was made by Whatman who supplied 100 without cost for this study.

The QM-A-quartz filters, which were found to have lower trace element concentrations in the series of blank analyses conducted in the laboratory, were used in this study. For 0.3 micron dioctyl phthalate smoke particles the QM-A-quartz materials were found to have 99.95% collection efficiency(26).

c) Impinger Train

The order and contents of the normal impinger train specified by AERM No. 4 are summarized in Table 2.5.

Impinger Number	Type	Contents gms
1	Modified	100 distilled deionized water
2	Greenburg-Smith	100 distilled deionized water
3	Modified	Empty
4	Modified	250-dessicant

Table 2.5 Method 4 Impinger Train

All impingers were immersed in an ice-water bath to condense water vapour for purposes of determining the moisture content of the gas stream and to enhance capture of submicron particulate passing through the filter.

For this trace element sampling program two additional impingers were added to the basic particulate matter sampling train providing the knock-out and absorption train detailed in Table 2.6:

Impinger Number	Type	Contents (gm)	Immersion Bath Temperature (°C)
1	Modified	100 6 M nitric acid	0
2	Greenburg-Smith	100 6 M nitric acid	0
3	Modified	Empty	0
4	Modified	Empty	-80
5	Modified	Empty	-80
6	Modified	250-dessicant	0

Table 2.6 Trace Element Impinger Train

Although a mixture of nitric and hydrochloric acids would be superior for dissolution of the trace metals, the presence of chloride during evaporation of the excess acid could result in significant losses of volatile halides (arsenic, selenium and vanadium). A six molar nitric acid concentration was chosen since this strength was successfully employed in an earlier study(12). Eight molar(26) concentrations have also been employed by previous investigators.

Deionized, distilled water, provided by the Energy Resources Conservation Board laboratory in Edmonton, was prepared following the procedure outlined in Appendix II. Trace metal grade Baker nitric acid from Lot No. 218042 was used to prepare the 6M solutions. Appendix II summarizes the composition of this reagent.

The last impinger contained Drierite (mesh size 10-20) which was discarded after each run. Loss of moisture removal capacity and erroneous moisture levels were readily detected by the blue to pink colour change.

d) Control Module

An approved EPA Model No. CU-4 sampling train manufactured by Andersen Samplers, Inc. was employed to sample isokinetically. The Pitot tube coefficients, orifice meter flow factor and dry gas meter correction factor were determined prior to field use on August 13 and 17, 1982 employing calibration procedures recommended in Method 7 of the AERM.(11) Post calibration of the train was performed on October 26, 1982.

Isokinetic sampling within ±10% at every point in each traverse was verified following the Method 4 procedure.

e) Leak Test

The 8-foot gas cooled probe was leak tested before each sampling traverse following AERM No. 4.(11) However, space limitations on the sampling platform precluded using this method for the 17-foot probe. The leak test for this probe was conducted by plugging the nozzle, pulling a 15-in. Hg vacuum on the probe alone and monitoring for leaks by observing the pressure gauge for a period of a minute. Any leak was readily detected within this time. The probe was inserted into the stack, with the impinger case suspended on the traversing rail. Then the remainder of the train was leak tested by plugging the ground glass joint, which connects to the probe in the oven, following the Method 4 procedure.

f) Sampling Conditions

Table 2.7 summarizes the relevant ranges of the total number of sample points, sampling times per point, total sample volumes, total sampling times and sampling rates employed in this study.

Total number of sample points:	20–48
Sampling time per point:	6 - 8 min
Total sample volumes:	75-150 ft^3 at reference conditions
Total sampling times	120–288 min
Sampling rates	0.3–0.7 ft^3/min

Table 2.7 Summary of Test Conditions.

A complete test for a plant consisted of a preliminary survey and a minimum of three particulate matter emission rate measurements.

G. PROCESS DESCRIPTION AND SOUR GAS PLANT OPERATING CONDITIONS

In order to allow effective correlation of incinerator stack emissions to plant operating conditions, Mr. R. Farion, Senior Gas Plant Inspector with the ERCB, was present in the control room for all tests and in constant touch with the source sampling team. Before, during and for several hours after each test run the information summarized in Table 2.8 was recorded on an hourly basis. In addition, Mr. Farion obtained process flow sheets, descriptive technical literature describing the process, engineering drawings of the stack detailing breeching elevations relative to sampling ports, plan views of the stack indicating stack diameter at the sampling level and a plot plan of the site indicating the stack position relative to plant boundaries for each plant tested.

RAW GAS INLET FLOW RATE
PLANT SALES GAS FLOW RATE
FEEDRATE TO SULPHUR PLANT
FEED TO FLARE STACK
STACK TEMP. (TOP AND BOTTOM)
STACK FLOW RATE
SO_2 CONCENTRATION

Table 2.8 Process Information Obtained at Each Plant on an Hourly Basis for Each Test Run.

1. Waterton Gas Plant (Shell Canada Resources Limited)

The Waterton Gas Plant, illustrated in Figure 2.9, consists of two parallel operations as indicated in Figures 2.10 and 2.11.

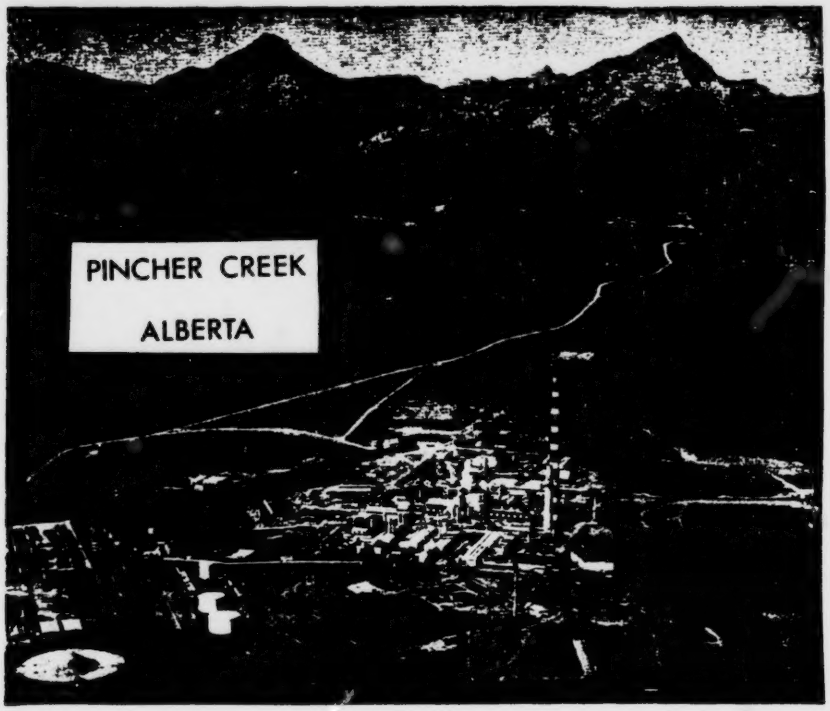
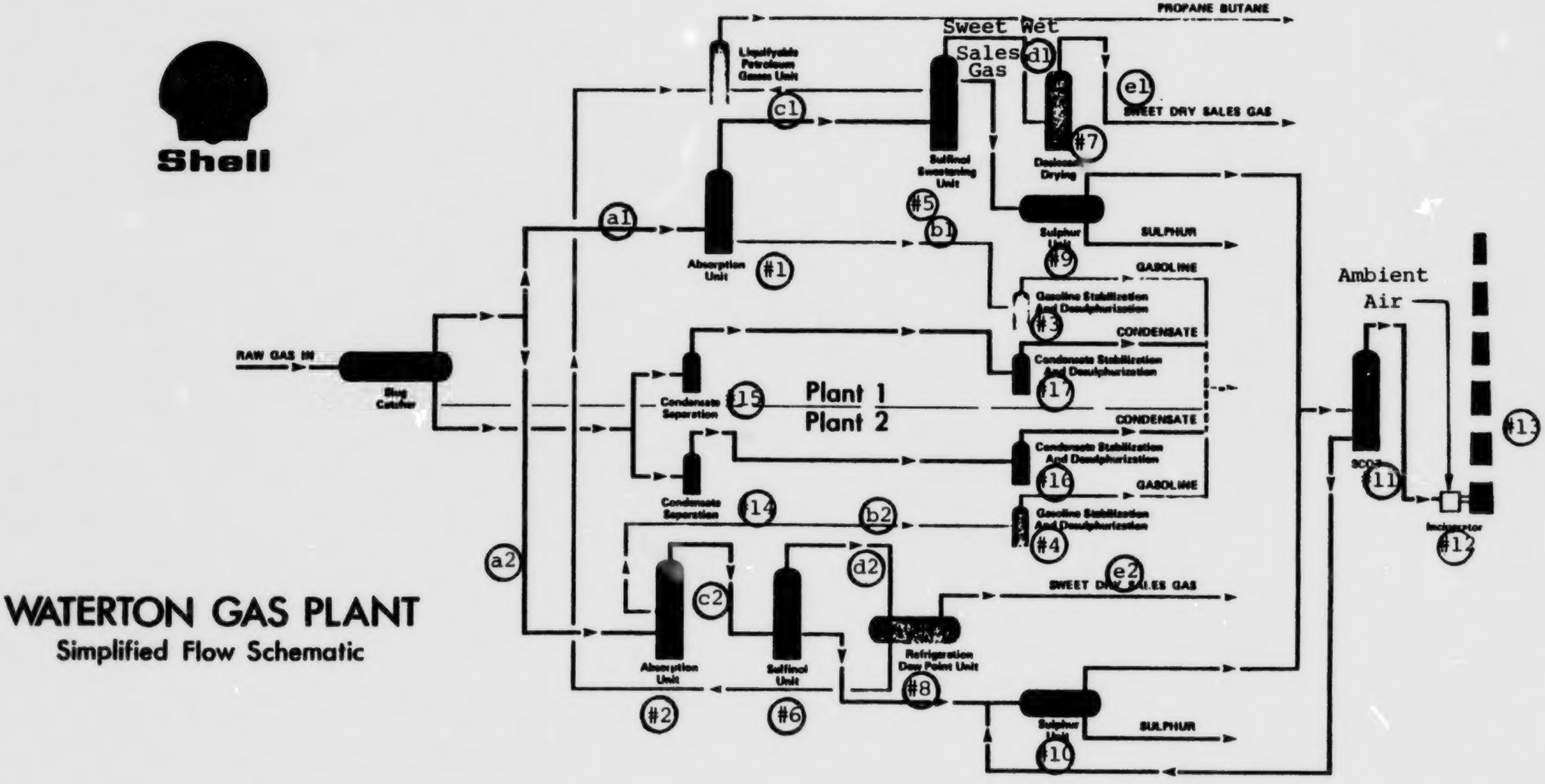


Figure 2.9 Shell Canada Resources Limited Waterton Gas Plant at Pincher Creek, Alberta.

Plant No. 1 was started up in January 1962 with a rated sales gas capacity of 120 MMCF/D. Expansion of the facility in 1967 increased production capabilities to 170 MMCF/D of sales gas. An additional output of 141 MMCF/D of sales gas became available with the commissioning of Plant No. 2 in 1971.

The Waterton Gas Plant was designed to handle up to 473 MMCF/D of raw natural gas from some 15 producing wells in the Waterton Gas Field which was discovered by Shell Resources Limited in 1957. The raw sour gas fed to the plant contains up to 17% hydrogen sulfide (H_2S) plus some carbon dioxide (CO_2). The "wet" inlet stream enters the plant by way of the slug catcher at a pressure of 1050 psig (7,250 kilopascals). Here, the entrained hydrocarbon liquids and water of condensation are separated from the gas by gravity.



Shell
WATERTON GAS PLANT
Simplified Flow Schematic
RAW GAS IN
Slug Catcher
a1
a2
Absorption Unit
#1
Absorption Unit
#2
c1
c2
Liquifyable Petroleum Gases Unit
PROPANE BUTANE
Sulfinol Sweetening Unit
#5
Sweet Wet Sales Gas
d1
Desiccant Drying
#7
e1
SWEET DRY SALES GAS
Sulphur Unit
#9
SULPHUR
b1
Gasoline Stabilization And Desulphurization
#3
GASOLINE
Condensate Separation
#15
Condensate Stabilization And Desulphurization
#17
CONDENSATE
Plant 1
Plant 2
Condensate Separation
#14
Condensate Stabilization And Desulphurization
#16
CONDENSATE
GASOLINE
b2
Gasoline Stabilization And Desulphurization
#4
Sulfinol Unit
#6
d2
Refrigeration Dew Point Unit
#8
e2
SWEET DRY SALES GAS
Sulphur Unit
#10
SULPHUR
Ambient Air
SCOT
#11
Incinerator
#12
#13

Figure 2.10 Simplified Flow Schematic for Waterton Gas Plant

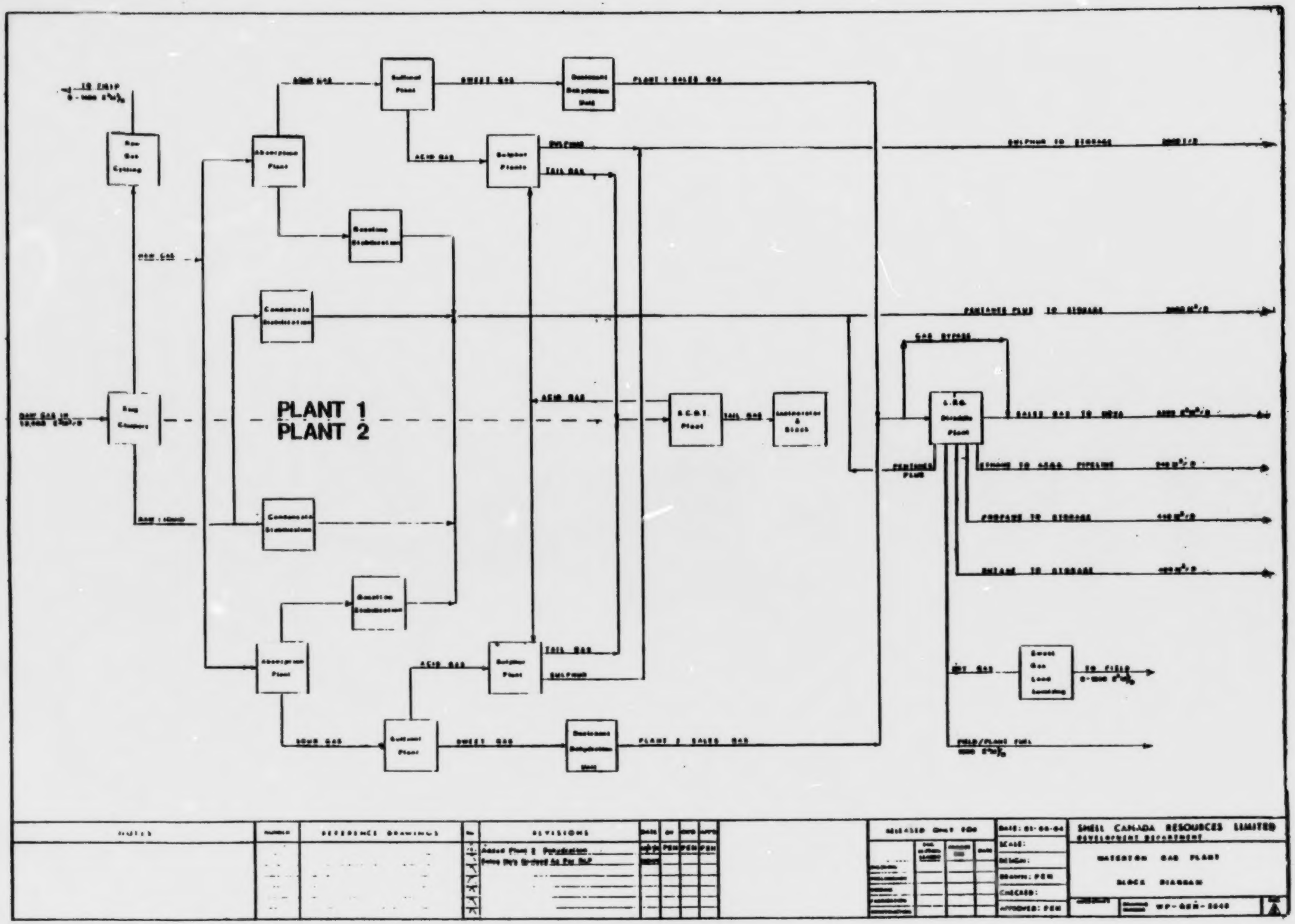

Raw Gas Cycling
Slug Catchers
Absorption Plant
Gasoline Stabilization
Condensate Stabilization
Sulfinol Plant
Sulphur Plant
Desiccant Dehydration Unit
SOUR GAS
SWEET GAS
ACID GAS
TAIL GAS
SULPHUR
PLANT 1 SALES GAS
PLANT 2 SALES GAS
PLANT 1
PLANT 2
S.C.O.T. Plant
Incinerator & Stack
GAS BYPASS
PENTANES PLUS
SULPHUR TO STORAGE
PENTANES PLUS TO STORAGE
SALES GAS TO NOVA
PROPANE TO STORAGE
BUTANE TO STORAGE
Sweet Gas Load Levelling
TO FIELD
FIELD/PLANT FUEL
NOTES
REFERENCE DRAWINGS
REVISIONS
SCALE:
CHECKED:
SHELL CANADA RESOURCES LIMITED
DEVELOPMENT DEPARTMENT
WATERTON GAS PLANT
BLOCK DIAGRAM

Figure 2.11 Waterton Gas Plant Block Diagram

The deliquified sour gas leaving the slug catcher is directed to Absorption Units (#1 and #2) by way of the paths a1 and a2 shown in Figure 2.9. A light oil circulating in a closed loop system operating at a pressure of 1,000 psig (6,900 kilopascals), is used to remove the butane, pentane, and propane fractions from the main gas stream. After separation of the butanes and pentanes from the circulating light oil is accomplished by boiling, these products are transferred to Gasoline Stabilization and Desulfurization Units (#3 and #4) by way of paths b1 and b2.

The main gas streams leaving the Absorption Units (#1 and #2) travel to the Sulfinol Units (#5 and #6) along routes c1 and c2 for sweetening through removal of hydrogen sulfide (H_2S) and carbon dioxide (CO_2). The sweetening process involves contacting the sour gas stream with a proprietary Shell development aqueous alkaline solution known as Sulfinol. This highly efficient gas absorption step produces a sweet wet gas still containing some propane as well as light hydrocarbons but negligible hydrogen sulfide (H_2S). The water vapor picked up during sweetening must be removed before the gas can be sold.

In Plant No. 1, the sweet wet gas is dried in a dessicant type regenerative dryer (Unit #7) where the water vapor is removed by adsorption on porous surfaces. Drying of the sweet wet gas leaving Plant No. 2, Sulfinol Unit (#6) is accomplished by cooling the stream to -20°F (-29°C) in the Refrigeration Dew Point Unit (#8).

The sweet dry sales stream containing less than 5 lb of water vapor per million cubic feet of gas is distributed by pipeline to Eastern Canada and the United States.

Regeneration of spent Sulfinol solutions (Units #5 and #6) involves removal of the acid gases (H_2S and CO_2) through distillation with subsequent transfer of the recovered hydrogen sulfide (H_2S) to the Claus Sulfur Units (#9 and #10). The Claus process is designed to convert roughly one-third of the hydrogen sulfide (H_2S) to sulfur dioxide (SO_2) according to the reaction.

$$H_2\,S(g) + 1\ 1/2\ 0_2\,(g) \longrightarrow H_2\,(0(g) + SO_2(g)$$

The remainder of the H_2S is reacted with the produced SO_2 in a catalyst bed at temperatures of 500-750°F to produce elemental sulfur according to the scheme

$$2H_2S(g) + SO_2(g) \longrightarrow 2H_2\,0(l) + 3\ S(l)$$

The gaseous sulfur is condensed and poured to form solid storage piles. When needed, the sulfur can be shipped out of the plant by rail in the form of slates or prills.

Under optimum operating conditions the Claus Sulfur Units (#9 and #10) are capable of converting 96% of the entering hydrogen sulfide (H_2S) to elemental liquid sulfur (S). Emissions of hydrogen sulfide (H_2S) to the environment are minimized by further processing of the gas streams leaving the Claus Units (#9 and #10) in the catalytic Shell Claus Off-Gas Treating (SCOT) plant (#11) which is designed to provide a 98.7% overall recovery of sulfur from the original raw gas stream. Residual levels of hydrogen sulfide (H_2S) are converted to sulfur dioxide in the Incinerator (#12) before the processed gas is exhausted through the 500 foot (152 meter) stack (#13).

The hydrocarbon liquids, that were originally separated from the incoming wet sour gas in the Slug Catcher, are treated in Condensate Separation Units (#14 and #15) before they are stabilized (Units #16 and #17) prior to pipeline shipment.

Liquified Petroleum Gases (L.P.G.) recovered during the sweetening (#5 and #6) and stabilization (#8) processes, are treated in the Liquefiable Petroleum Gases Unit (#18) with eventual separator into propane and butane.

2. Pincher Creek Gas Plant (Gulf Oil Canada Limited)

Figure 2.12 provides a detailed flow diagram for the Pincher Creek Gas Plant. A simplified version is illustrated in Figure 2.13. The raw sour gases from the Lookout Butte and Pincher Creek Fields have hydrogen sulfide (H_2S) contents ranging from 3.9 to 11 per cent. Entrained hydrocarbon liquids and water are removed from the entering wet sour gas stream in the Inlet Separator. The water is returned to the field for disposal through Injection Wells. The sour hydrocarbon condensate from the Inlet Separators is fed to the Condensate Stabilizer where hydrogen sulfide (H_2S) and lighter hydrocarbons are removed to leave a stable condensate product.

Deliquified sour gases from the Inlet Separators are combined with the sour gases recovered from the Condensate Stabilizer for treatment in the Amine Units. The acid gases removed from the Amine Units contain hydrogen sulfide (H_2S) and carbon dioxide (CO_2) which are fed to the Sulfur Plants for production of elemental sulfur. Emission of hydrogen sulfide to the atmosphere is minimized by incinerating the gases leaving the sulfur plants prior to venting through the tall stack.

Sweet gases leaving the Amine Units are fed to the Absorption Plant where residual heavier hydrocarbons and hydrogen suilfide (H_2S) are removed. The hydrogen sulfide (H_2S) is compressed along with that recovered from the Condensate Stabilizer and recycled to the Amine Units.

Gases leaving the Absorption Plant are dried in the Dehydration Units before distribution through pipelines to existing markets.

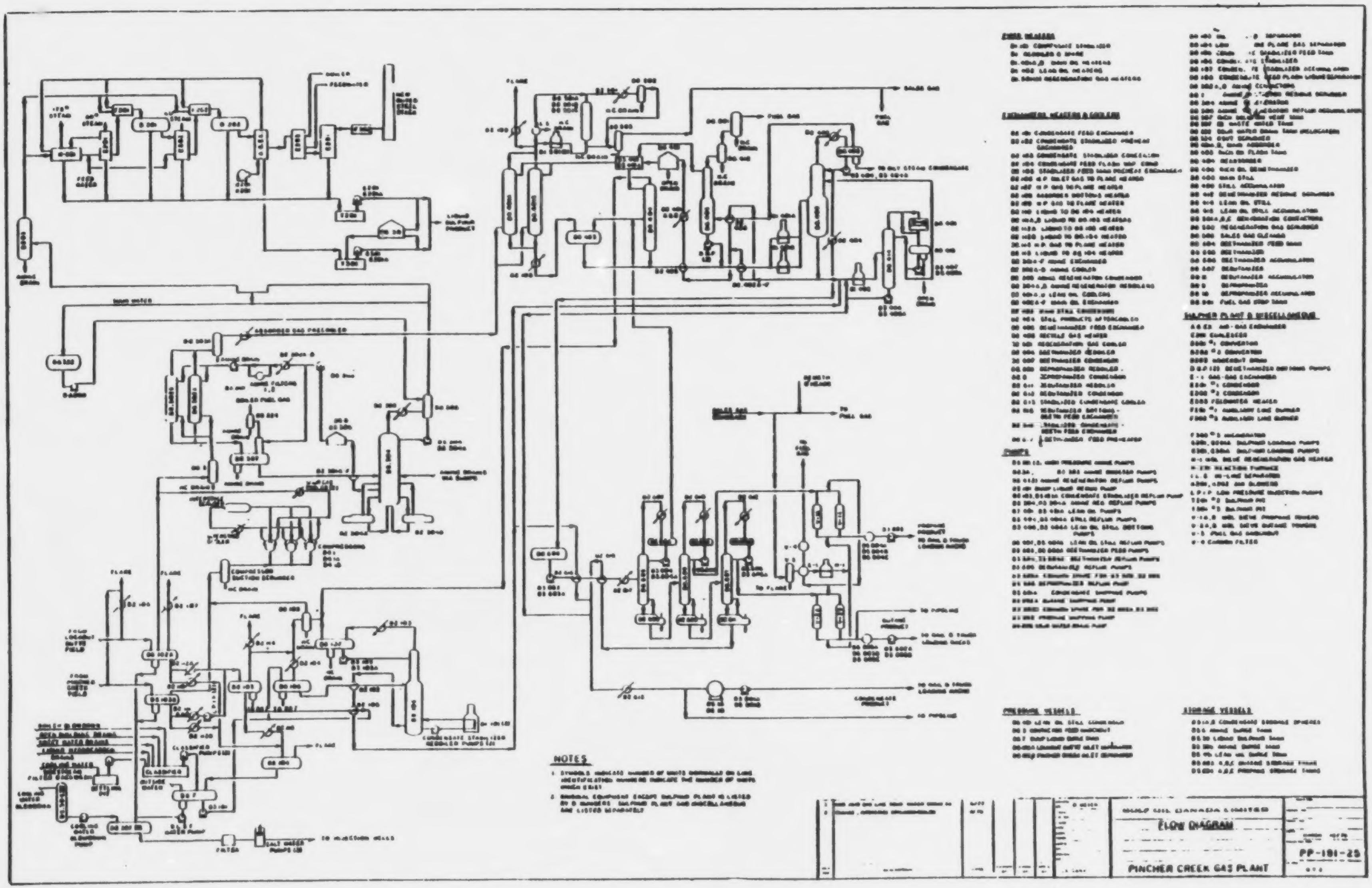

NOTES
PRESSURE VESSELS
STORAGE VESSELS
PUMPS
SULPHUR PLANT & MISCELLANEOUS
FLOW DIAGRAM
PINCHER CREEK GAS PLANT
PP-101-25

Figure 2.12 Detailed Flow Diagram for Pincher Creek Gas Plant

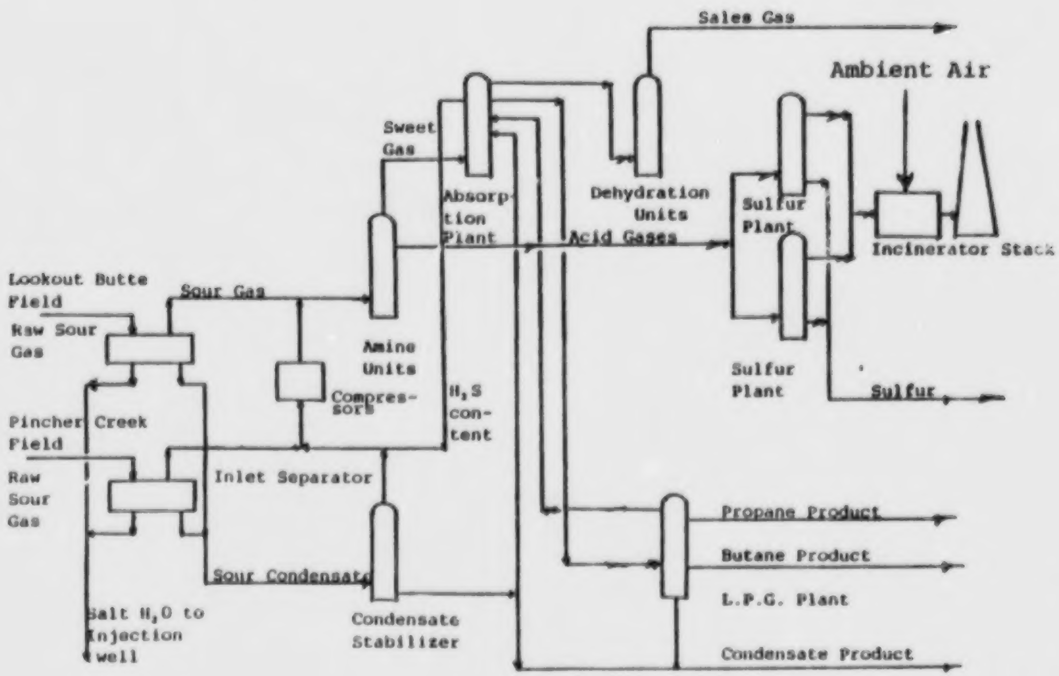

Lookout Butte Field
Raw Sour Gas
Pincher Creek Field
Raw Sour Gas
Salt H_2O to Injection well
Sour Gas
Inlet Separator
Sour Condensate
Compressors
Amine Units
Condensate Stabilizer
Sweet Gas
H_2S content
Absorption Plant
Dehydration Units
Acid Gases
Sales Gas
Sulfur Plant
Sulfur Plant
Ambient Air
Incinerator Stack
Sulfur
Propane Product
Butane Product
L.P.G. Plant
Condensate Product

Figure 2.13 Simplified Flow Schematic for Gulf Oil Canada Limited Pincher Creek Gas Plant

The heavier sweet gases from the Absorption Plant are fed to the Liquefiable Petroleum Gases (LPG) Plant where propane butane and heavier hydrocarbon condensates are separated for subsequent distribution by rail, truck or pipelines.

III. SAMPLE RECOVERY

Quantitative recovery of the samples from all parts of the train required a rigorous and meticulous procedure which took 3 to 4 hours to complete.

A. INTRODUCTION

Upon completion of a test the main power switch and both flow control valves were closed. After the probe was rotated so that the nozzle inlet faced downstream, the probe assembly was pushed into the stack so that the impinger case was accessible from the sampling platform. Then the oven door was opened. The glassware was allowed to cool and the glass probe liner was disconnected from the cyclone-bypass. After the probe glass ball socket and the cyclone-bypass ground glass joint were sealed the complete impinger case was removed from the traversing rail and safely positioned on the sampling platform.

The probe assembly was then slowly removed from the port while maintaining cooling air flow through the probe jacket. When the probe could be safely handled with high temperature heat resistant gloves it was removed from the port. The nozzle tip was sealed and protective end caps were placed over the nozzle-Pitot-RTD and the ground glass ball socket to prevent physical damage to the exposed parts. Cooling air flow was maintained until the probe could be safely handled with bare hands.

While the probe was cooling the impinger assembly was sealed and lowered to ground level for sample recovery in the laboratory. The probe cleanup which took place at the sampling platform level, was facilitated by the use of a custom built support system which rode on the traversing rail. A detailed step-by-step cleanup procedure follows for the nozzle-probe, filter, impingers in the ice-water bath and impingers in the dry ice-acetone bath. Figure 3.1 details sample recovery from the component parts of the train.

B. NOZZLE-PROBE

For cleanup purposes, the protective caps were removed from both ends of the probe assembly and the sealed nozzle exterior wiped with paper towels.

1. Nozzle

After removing the nozzle and sealing the end of the glass liner, the nozzle was rinsed with 6M nitric acid (see Appendix II) from a polyethylene wash bottle, into a labelled 500 mL sample bottle A1.

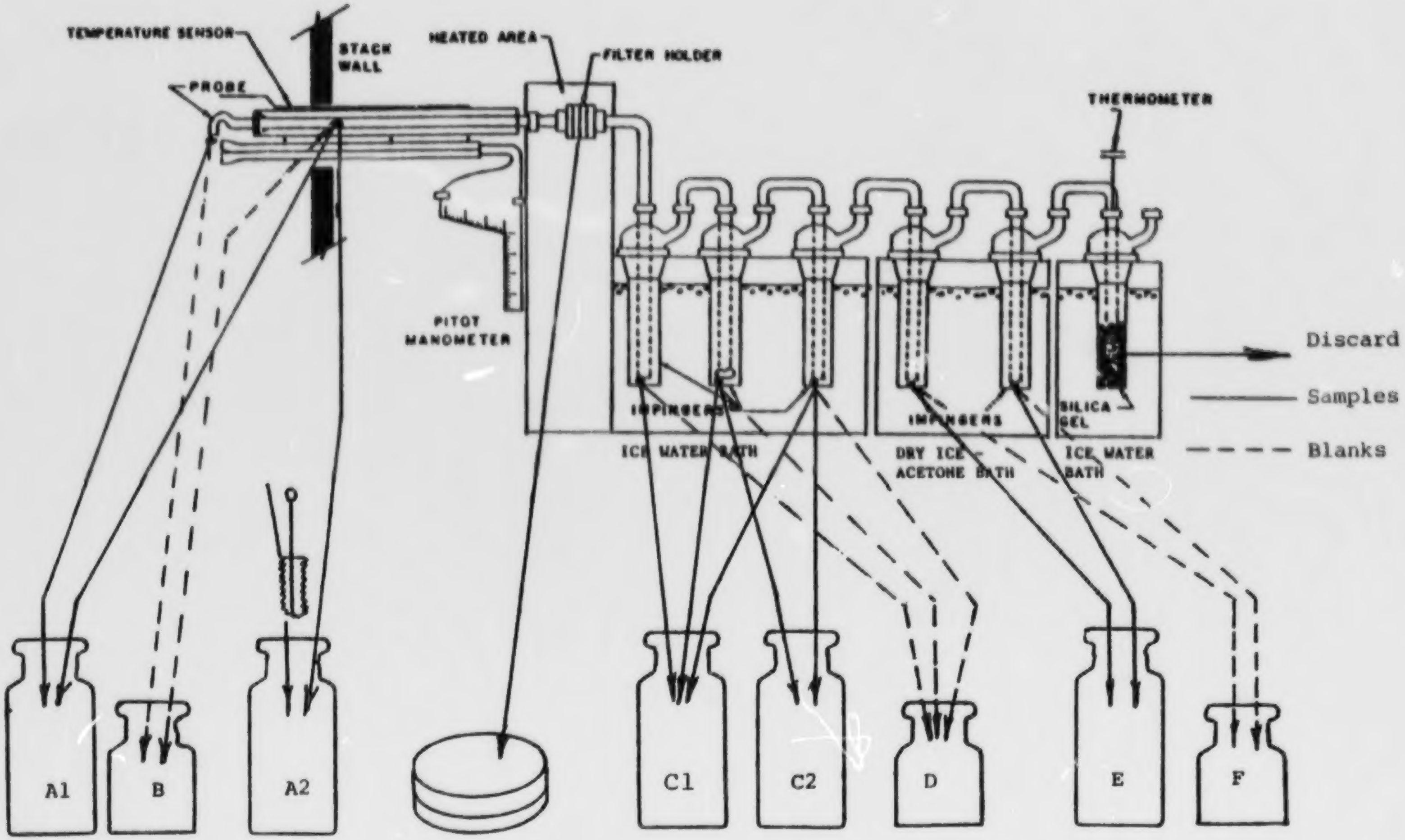

TEMPERATURE SENSOR
PROBE
STACK WALL
HEATED AREA
FILTER HOLDER
THERMOMETER
PITOT MANOMETER
IMPINGERS
ICE WATER BATH
IMPINGERS
DRY ICE - ACETONE BATH
SILICA GEL
ICE WATER BATH
Discard
Samples
Blanks
A1
B
A2
C1
C2
D
E
F

Figure - 3.1 Sample Recovery Procedure

The interior of the nozzle was vigorously scrubbed with a nylon bristle brush mounted on a stainless steel wire handle. The rinsing-brushing operations continued until the washings showed no visible particles. Approximately 150 mL more of 6M HNO_3 were used in this step. All washings were collected in sample bottle A1.

Finally, the nozzle was rinsed with deionized distilled water which was discarded. The clean nozzle was placed into a protective polyethylene bag for use in the next test.

All sample bottles were new and constructed of borosilicate glass with Teflon seals in the screw type caps. Prior to use, the new sample bottles were cleaned in a glass washer with Alconox water solution then rinsed with 6-M nitric acid (HNO_3) and finally deionized distilled water (see Appendix I). Immediately prior to field use, the bottles were rinsed with 0.1M HNO_3.

2. Probe

The probe assembly was placed in the support system and the exterior of both liner ends wiped with paper towels. The probe liner was cleaned by first tilting and rotating the probe while squirting approximately 350 mL of 6M HNO_3 into the upper end. The nitric acid wash was collected in labelled container A1.

Next the nylon probe brush, with stainless steel wire handles and extensions, was used to vigorously scour the liner interior. Another 350 mL of 6M nitric acid were passed through the tilted probe liner, while rotating, and collected into a second container, A2. This procedure was repeated until the washings showed no visible particles. Then the liner was visually inspected to confirm that it was clean and minimal rinse acid was held up in the liner. The probe brush was rinsed into container, A2 and both sample bottles, A1 and A2 were marked for liquid level and carefully stored.

The liner was rinsed with deionized distilled water which was discarded, both ends sealed and the protected covers replaced.

3. Nozzle-Probe Blanks

Before the next test, both the nozzle and probe liner were rinsed with 0.1 M HNO_3 which was collected in labelled container B (100 mL). This blank constituted an additional test for gross contamination which might occur during storage and/or shipment between tests.

The container liquid level was marked and the blank stored for subsequent trace element analysis. The nozzle and probe were rinsed with distilled water and then put together for the test to follow.

C. FILTER

In the laboratory the filter holder was carefully removed from the oven and separated from the cyclone bypass.

1. Filter Removal

The quartz filter was carefully removed from the filter holder using a pair of nonserrated nylon tipped tweezers and a Teflon coated razor blade to lift the filter from the gasket.

The filter, which had been tared to the nearest ±0.1 mg at constant weight in a 50 percent relative humidity atmosphere, was placed into a labelled disposable Petri dish made of polystyrene.

Next the gasket was carefully scraped with the Teflon coated razor to remove any filter matter adhering to the surface. This material was added to the Petri dish, which was sealed, then carefully stored for later trace element analysis and final weighing at 50% relative humidity.

2. Cyclone-Bypass and Filter Front End

The silicone grease was removed from the ground glass joints and the cyclone bypass rinsed with 6 M $HN0_3$ into container A2. The front half of the borosilicate glass filter holder was similarly cleaned into the same container. After brushing and rinsing until clean, the final liquid level was noted on container A2.

The cyclone-bypass and filter holder were then rinsed with 0.1 M $HN0_3$ and deionized distilled water to ready them for reassembly.

D. IMPINGER TRAIN

The two cold trap impingers (dry ice-acetone bath) were separated from the four impingers in the ice-water bath by removing the glass connections which were placed on disposable polyethylene sheets. The high temperature silicon grease* was then removed from the ground glass joints on every piece of connecting glassware and impinger using disposable paper towels.

1. Moisture Determination

Water was wiped from the outside walls of each impinger with absorbent paper. Then all six impingers were weighed to the nearest ±0.1 gm on a trip balance to allow stack gas moisture determinations following the condensation method (AERM-3).(11) The Drierite contained in impinger 6 was discarded.

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*Dow Corning High Vacuum Grease.

2. Impingers 1, 2 and 3 at Ice-Water Bath Temperature

The contents of impingers 1, 2 and 3 were emptied into labelled container C1 (and C2 if required). Then 20-30 mL of 6M HNO_3 from a polyethylene wash bottle was used to rinse each impinger. The rinses were collected into container C1 or a second container C2.

After brushing the inlet and outlet passages of each impinger, they were rinsed again with 6M HNO_3. Approximately 25-mL of 6M HNO_3 were added to each impinger, which was shaken vigorously for 2-3 minutes. The washes were emptied into container C2. These procedures were continued until the surfaces were visibly clean. Normally the total rinse volumes, initial impinger acid charges, and condensed water vapor required two 500 mL sample bottles.

3. Blank - Impingers 1, 2, and 3

Before the next test approximately 25 mL of 0.1 M HNO_3 were added to each impinger which was vigorously shaken for 2-3 minutes. The washes were poured into labelled container D to constitute a blank for the next test. This additional step provided a check on possible gross contamination during storage and/or shipment between tests.

Each impinger was then flushed with deionized distilled water which was discarded.

Impingers 1 and 2 had approximately 100 mL of 6M HNO_3 added to the marked level for use in the next test.

After taring, the water-bath impingers (1, 2, and 3) were then assembled for the next test.

4. Impingers 4 and 5 at Dry Ice-Acetone Bath Temperature

The contents of impingers 4 and 5 were emptied into labelled container E. Each impinger was rinsed with 20-30 mL of 6M HNO_3 with the rinses being added to the sample bottle. Inlet and outlet passages were brushed and a final wash with 6M HNO_3 was completed in the same manner as for impingers 1, 2 and 3.

5. Blank-Impingers 4 and 5

At the start of the next test approximately 25 mL of 0.1M HNO_3 were added to each impinger which was vigorously shaken for 2-3 minutes. The washes were poured into labelled container F which constituted a blank for the next test. After flushing with deionized distilled water, which was discarded, impingers 4 and 5 were weighed and assembled.

6. Connecting Glassware

The glassware used to connect the impinger train was removed from the disposable polyethylene sheets mentioned earlier and any material adhering to the walls was rinsed with 6M HNO_3 into appropriate containers. After brushing the walls, the connectors were again rinsed with 6M HNO_3. The rinses from glassware connecting impingers 1, 2 and 3 were added to bottle C1 or C2 and the rinses from impingers 4 and 5 connectors were added to bottle E. Final deionized distilled water rinses readied the connectors for the subsequent test.

IV. ANALYTICAL PROCEDURES

Literature reviews,(14-17) discussions with chief chemists at industrial,(21) academic(29) and regulatory organizations(20) as well as personal experiences suggested that atomic absorption spectrometry (AAS) offered the most viable approach to the measurement of the 29 trace elements of concern to this investigation. Generally, atomic absorption is relatively interference free, however, high concentrations of dissolved salts can produce interference by scattering, particularly when analyses are carried out at UV wavelengths. Although atomic absorption is normally not a sensitive technique for arsenic, selenium and mercury determinations, modification of the standard procedures can lower detection limits by 2 orders of magnitude. For example, furnace techniques can be used to improve analyses for selenium, arsenic and vanadium. The cold vapour procedure has been reported to be a reliable method of determining trace amounts of mercury(12, 27-28).

To ensure complete dissolution of all but the most inert metallic species that were collected as particulate matter, it would be desirable to use a mixture of nitric and hydrochloric acids for preparation of the solutions to be subjected to atomic absorption spectrometry. However, the use of hydrochloric acid must be limited to prevent significant losses of the volatile halides of arsenic, selenium and vanadium during the evaporation of excess acid. Consequently, all sample preparation was done in parallel to provide one group of metals in nitric acid and another in hydrochloric acid. Table 4.1 details the selection of acids for the dissolution of the metals pertinent to this investigation. Also provided are the analytical parameters for atomic absorption analyses.

A. DEVELOPMENT

1. Pre-Test Program

Since it was not possible to predict the amount of any element that would be collected in any component of the sampling train, analytical procedures were developed for trace level determinations. Consequently, it was important to quantify the contribution of any metallic species from the distilled water, nitric acid and filters used during sample collection and/or recovery as well as the stainless steel liner that was proposed for the larger incinerator stacks.

All preliminary analyses of distilled water, nitric acid, filters and probe and impinger washings were carried out by Analytic and Biological Laboratories, Inc.(30) with an Inductively Coupled Argon Plasma (ICAP) Spectrometer manufactured by Applied Research Laboratories of Sunland, California. The instrument specifications are detailed in Appendix III.

Element		Analytical Wavelength	Detection Limit (mg/L)	Sensitivity (mg/L)	Flame Type	Optimum Concentration Range (mg/L)	Acid Prep	Comments
Ag	Silver	3281	0.05	0.03	A-Ac	0.1-2.0	HNO_3	
Al	Aluminum	3093	1.0	0.4	N-Ac	5.0-100	HCl	Add 2000 ppm K
As	Arsenic	1937	0.005	0.005	furnace	0.005-0.05	HNO_3	
B	Boron	2497	10	9	N-AC	50-500	HNO_3	
Be	Beryllium	2349	0.02	0.01	N-AC	0.1-2.0	HCl	Add 5% 8-hydroxyquinolin
Cd	Cadmium	2288	0.02	0.01	A-AC	0.1-2.0	HNO_3	
Co	Cobalt	2407	0.2	0.05	A-AC	0.5-10	HCl	
Cu	Copper	3247	0.1	0.03	A-AC	0.5-10	HNO_3	
Cr	Chromium	3579	0.2	0.06	N-AC	0.5-10	HNO_3	
Fe	Iron	2483	0.1	0.04	A-AC	0.5-10	HNO_3	
Ga	Gallium	2874	2.0	1.5	N-AC	5-100	HNO_3	Add 2000 ppm K
Ge	Germanium	2651	2.0	1.0	N-AC	5-100	HNO_3	
Hg	Mercury	2537	0.01	0.01	Cold vapor	0.01-0.1	Special prep	
In	Indium	3040	1.0	0.2	N-AC	5.0-100	HNO_3	Add 2000 ppm K
Li	Lithium	6708	0.05	0.02	N-AC	0.1-2.0	HCl	Add 2000 ppm K
Mn	Manganese	2795	0.05	0.02	A-AC	0.1-2.0	HNO_3	
Mo	Molybdenum	3133	0.5	0.2	N-AC	1.0-20	HNO_3	Add 1000 ppm Al
Ni	Nickel	2320	0.2	0.06	A-AC	0.5-10	HNO_3	
Pb	Lead	2170	0.2	0.1	A-AC	0.5-10	HNO_3	
Sb	Antimony	2176	0.4	0.2	A-AC	1.0-20	HCl	
Sc	Scandium	3912	0.5	0.1	N-AC	2.0-50	HCl	Add 2000 ppm K
Se	Selenium	1960	0.01	0.01	Furnace	0.01-0.05	HNO_3	
Sn	Tin	2355	1.0	1.0	N-AC	5.0-100	HCl	
Sr	Strontium	4607	0.05	0.1	N-AC	0.1-2.0	HNO_3	Run by emission add 2000 ppm K
Te	Tellurium	2143	0.5	0.2	A-AC	1.0-2.0	HNO_3	
Ti	Titanium	3643	1.0	1.0	N-AC	10-200	HCl	Add 2000 ppm Al
Tl	Thallium	2768	0.5	0.1	A-AC	1.0-20	HNO_3	
V	Vanadium	3185	0.02	0.01	Furnace	0.05-0.5	HNO_3	
Zn	Zinc	2138	0.03	0.01	A-AC	0.1-2.0	HCl	

Table 4.1 Summary of Analytical Parameters for Atomic Absorption Analysis

Distilled water from the University of Calgary and the University of Alberta as well as demineralized water prepared by the Energy Resources Conservation Board Laboratory in Edmonton, Alberta were analyzed for trace metal contents.

Blank samples of Baker Instra-Analyzed nitric acid were subjected to ICAP analysis during two separate pre-testing programs involving determination of background levels of metals on fibre glass and micro-quartz filters and an estimation of the leaching effect when stainless steel probe liners are washed with 6M nitric acid.

Conventional 125 mm borosilicate glass fibre and 125 mm quartz microfibre filters obtained from Whatman Laboratory Products, Inc. Paper Division(31) were subjected to the proposed nitric and hydrochloric acid leaching procedures. In addition, one sample of 8 x 10 inch quartz microfibre hi-vol filter was extracted with nitric and hydrochloric acids. The resultant solutions were examined with the ICAP spectrometer for all 29 elements of interest to this study.

After construction of the 17 foot probe had been completed, the internal stainless steel liner, the three impingers, the two cold trap impingers and all connecting glassware comprising the stack sampling train were washed with volumes of 6M nitric acid solutions that matched the amounts projected for onsite sample recovery after each test. All of these washings were subjected to ICAP spectrometry.

2. Preliminary Field Testing

The samples collected during the preliminary testing of the Canterra - Ram River plant on August 25, 1982 were used to finalize the analytical procedures for all samples acquired during the trace element emission study(13).

After the preliminary procedures failed to detect the presence of any of the 29 metal species, it became necessary to achieve as much concentration as possible before submitting the final samples to the atomic absorption techniques. Analysis of large volumes of dilute probe assembly washes and impinger liquids was enhanced by pre-concentration by factors ranging from 4 to 13.

Since there was no way to predict what metals would be collected from any stack at any time the analytical procedures had to be reliable for trace metal determinations in the presence of unknown amounts of other components. Although it was not possible to study all potential interferences resulting from the matrix effects of 29 elemets in a solution, the significance of any interferences was assessed by running recoveries on all 29 elements dissolved in one solution.

B. PLANT TESTS

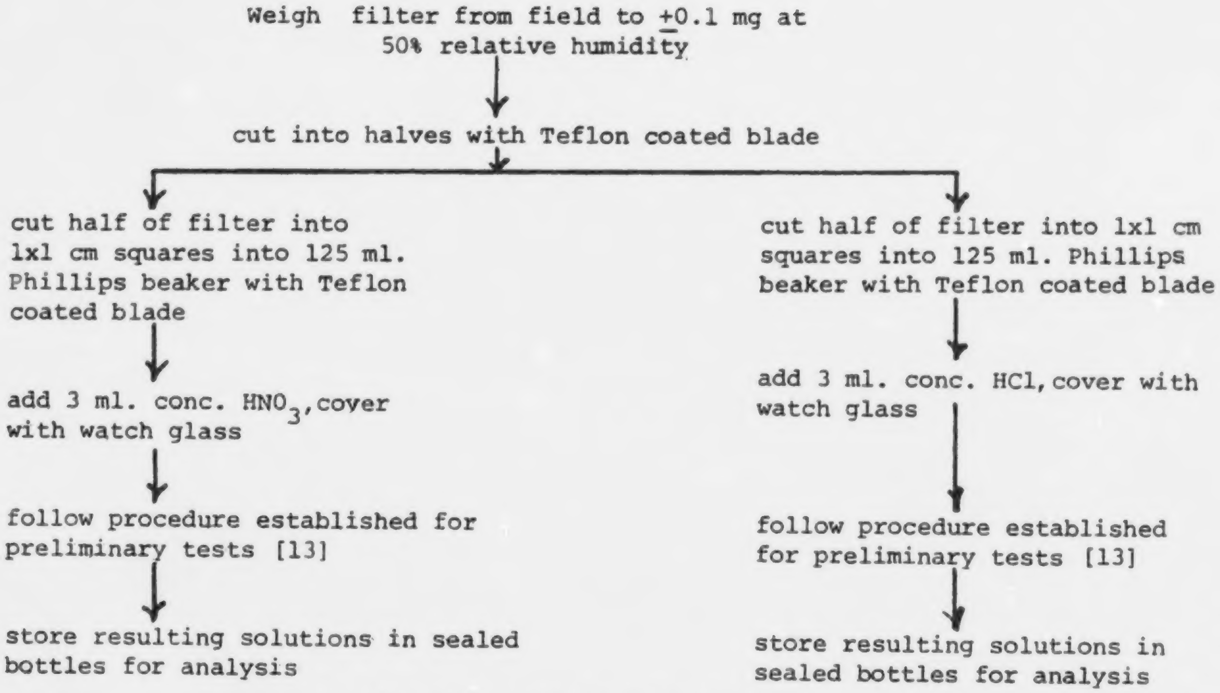
As shown in Figure 4.1 the filters from all final tests were cut into halves to provide more concentrated HNO_3 and HCl solutions of the metals under investigation. All test liquid catches were treated according to the flowsheet illustrated in Figure 4.2. Impingers 1 , 2 and 3 were combined and the total volume was reduced to 25 mL by evaporation. Similarly the combined volume of impingers 4 and 5 was reduced to 25 mL by evaporation.

The preparation of filter and solution blanks is illustrated in Figure 4.3. Because of the potential for interferences and matrix effects to be created as a result of the complexity of the solutions being analyzed, it was essental to determine the recovery of each metal species by creating synthetic systems of known composition of each of the 29 elements under investigation. Clean filters and distilled water samples were spiked with appropriate volumes of the 1000 ppm AA standards according to the schemes illustrated in Table 4.2 and Table 4.3, respectively. The preparations of solutions from the filter and liquid recoveries are illustrated in Figures 4.4 and Figure 4.5, respectively. All filters and solutions corresponding to final tests, blanks and recoveries were treated similarly with respect to the evaporation and dilution steps described previously(13).

C. ATOMIC ABSORPTION SPECTROMETRY

Atomic absorption analyses were carried out with an Instrumentation Laboratory Model IL 551 Video I double beam atomic absorption/atomic emission spectrophotometer with microcomputer, cathode-ray tube display. Flameless analyses were performed using a Varian Model 975 spectrophotometer equipped with a Varian temperature controlled furnace Model GTA95. The instruments were equipped to use air/acetylene, nitrous oxide/acetylene, or argon/hydrogen flames depending on the element being investigated. Table 4.1 summarizes the flame types for each element.

Limits of detection of each metal in mg/L were established by analyzing the lowest standard 10 times in order to determine the mean value of the absorbance and the standard deviation in terms of absorbance. Each detection limit shown in Table 4.1 was evaluated according to the expression:



Weigh filter from field to ±0.1 mg at 50% relative humidity

cut into halves with Teflon coated blade

cut half of filter into 1x1 cm squares into 125 ml. Phillips beaker with Teflon coated blade

add 3 ml. conc. HNO_3, cover with watch glass

follow procedure established for preliminary tests [13]

store resulting solutions in sealed bottles for analysis

cut half of filter into 1x1 cm squares into 125 ml. Phillips beaker with Teflon coated blade

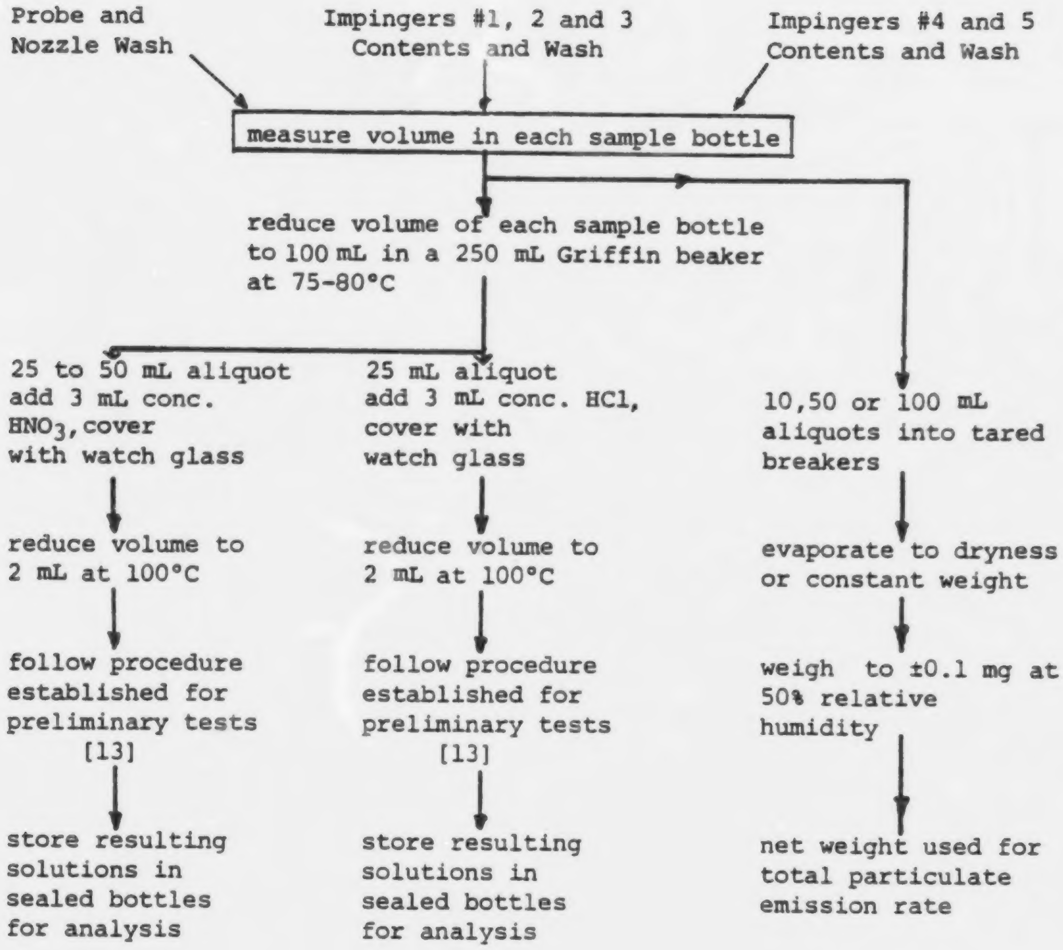
add 3 ml. conc. HCl, cover with watch glass

follow procedure established for preliminary tests [13]

store resulting solutions in sealed bottles for analysis

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.1 Treatment of Filters From Final Tests.


Probe and Nozzle Wash
Impingers #1, 2 and 3 Contents and Wash
Impingers #4 and 5 Contents and Wash
measure volume in each sample bottle
reduce volume of each sample bottle to 100 mL in a 250 mL Griffin beaker at 75-80°C
25 to 50 mL aliquot add 3 mL conc. HNO3, cover with watch glass
reduce volume to 2 mL at 100°C
follow procedure established for preliminary tests [13]
store resulting solutions in sealed bottles for analysis
25 mL aliquot add 3 mL conc. HCl, cover with watch glass
reduce volume to 2 mL at 100°C
follow procedure established for preliminary tests [13]
store resulting solutions in sealed bottles for analysis
10,50 or 100 mL aliquots into tared breakers
evaporate to dryness or constant weight
weigh to ±0.1 mg at 50% relative humidity
net weight used for total particulate emission rate

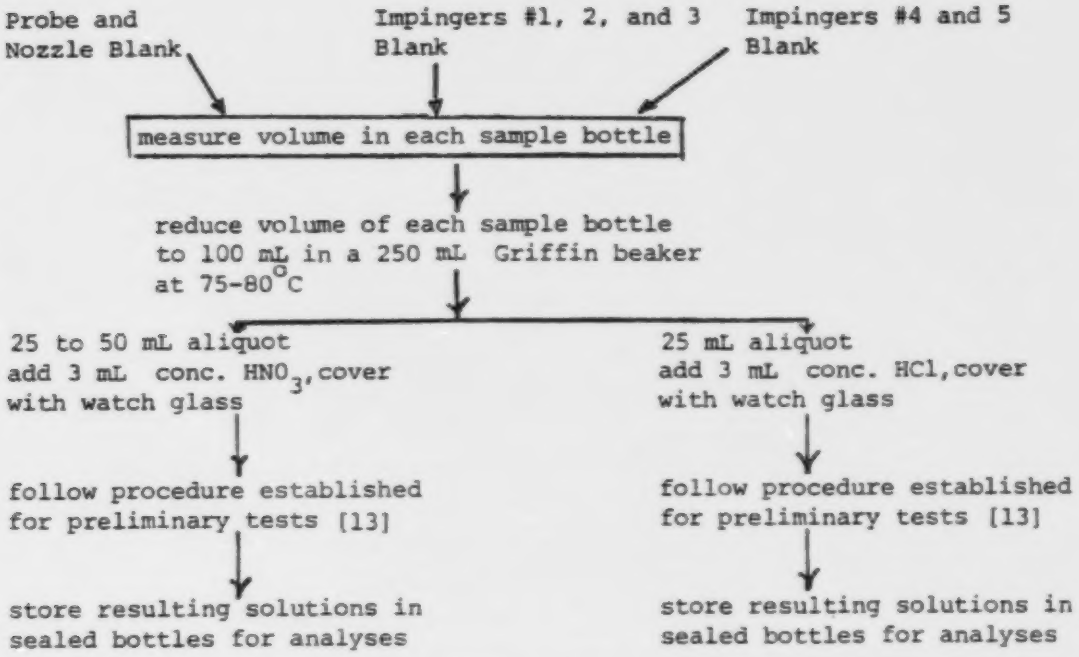
Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.2: Treatment of Solutions From Final Tests

Filter Analysis

Follow procedures established for field and laboratory blanks on filters used for preliminary survey

Solution Analyses


Probe and Nozzle Blank
Impingers #1, 2, and 3 Blank
Impingers #4 and 5 Blank
measure volume in each sample bottle
reduce volume of each sample bottle to 100 mL in a 250 mL Griffin beaker at 75-80°C
25 to 50 mL aliquot add 3 mL conc. HNO3, cover with watch glass
follow procedure established for preliminary tests [13]
store resulting solutions in sealed bottles for analyses
25 mL aliquot add 3 mL conc. HCl, cover with watch glass
follow procedure established for preliminary tests [13]
store resulting solutions in sealed bottles for analyses

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.3 Preparation of Blanks for Filter and Solution Analyses

HNO_3 TREATMENT		HCl TREATMENT	
Element	Amount Added uL	Element	Amount Added uL
Mn	25	Ti	2000
Ni	100	Co	100
Cu	100	Zn	25
Ga	1000	Sb	200
Ge	1000	Be	25
Mo	200	Al	1000
Pb	100	Sn	1000
Sr	50	Li	25
B	1000	Sc	200
Ag	100		
Tl	200		
In	1000		
Te	400		
Fe	100		
As	2		
Se	2		
V	10		
Hg	5		
Cd	25		
Cr	100		

Table 4.2 Amounts of Standards Added to Filters for Recoveries Using 1000 ppm Standards

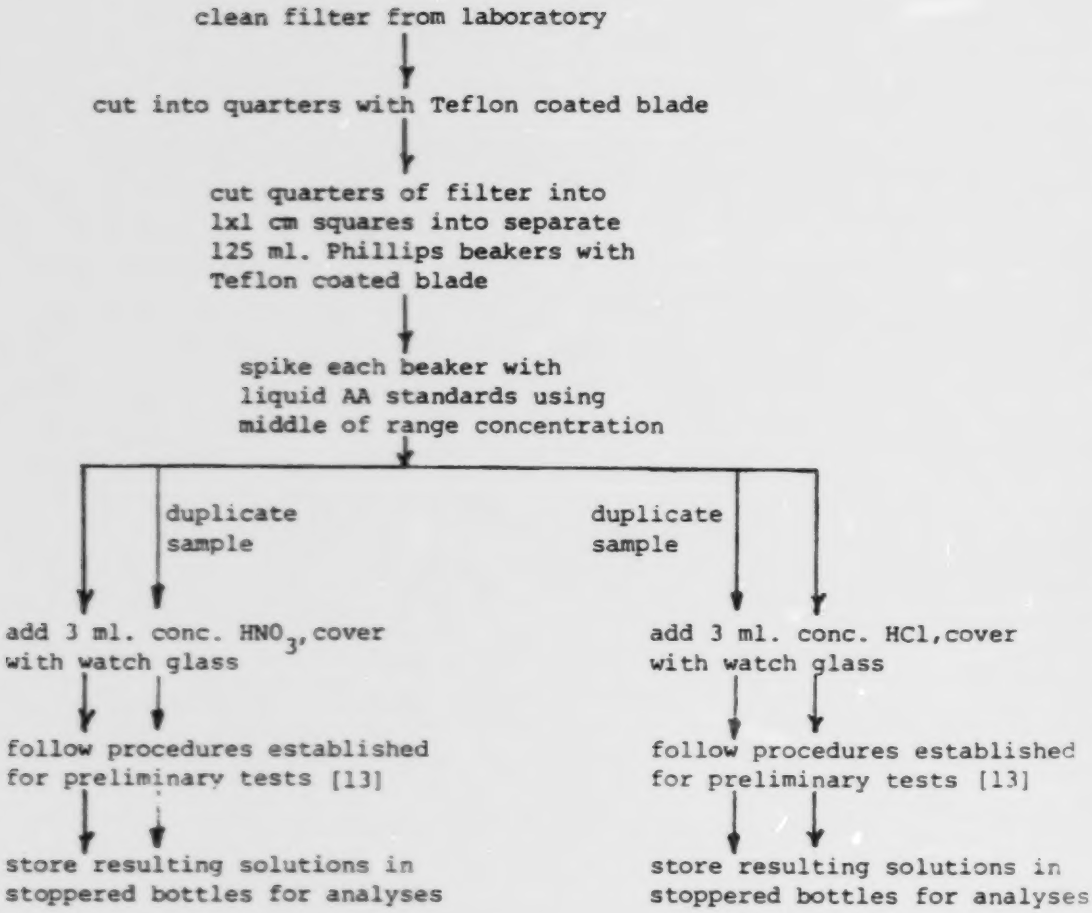
HNO$_3$ TREATMENT

Element	Amount Added uL
Mn	25
Ni	250
Cu	250
Ga	1000
Ge	1000
Mo	100
Cd	25
Pb	250
Sr	50
B	6000
Ag	25
Tl	500
In	3000
Te	500
Fe	250
As	5
Se	5
V	10
Hg	10
Cr	100

HCl TREATMENT

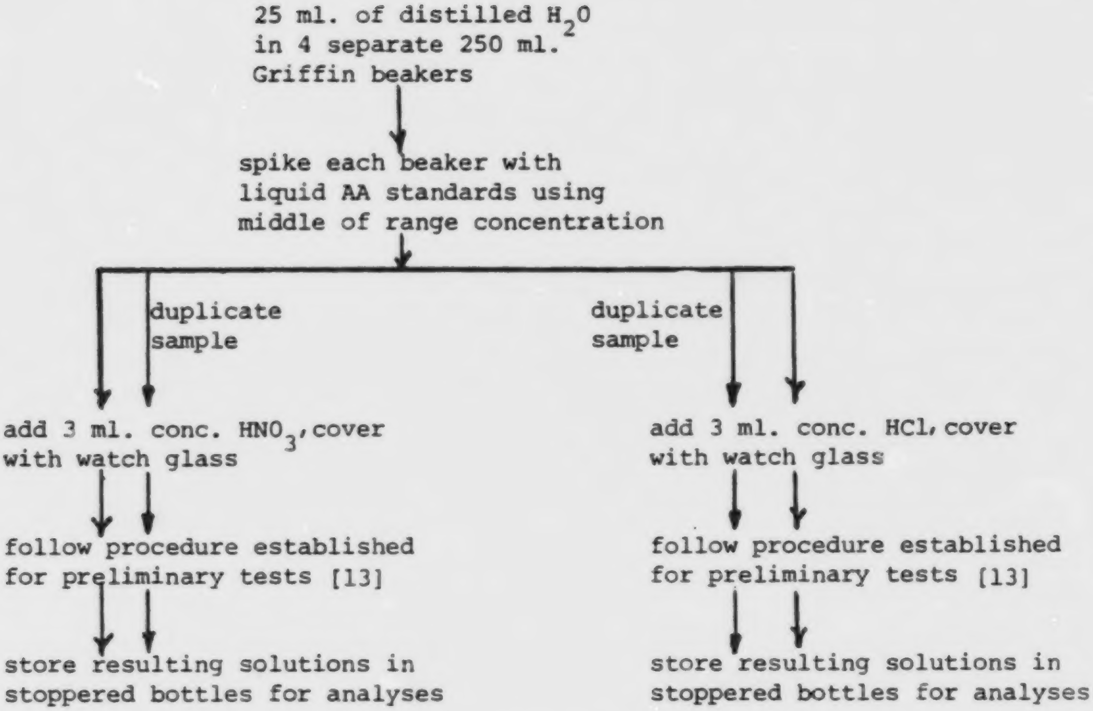
Element	Amount Added uL
Ti	1000
Co	100
Zn	25
Sb	200
Be	25
Al	1000
Sn	500
Li	25
Sc	200

Table 4.3 Amounts of Standards Added to Solutions for Recoveries Using 1000 ppm Standards


clean filter from laboratory
cut into quarters with Teflon coated blade
cut quarters of filter into 1x1 cm squares into separate 125 ml. Phillips beakers with Teflon coated blade
spike each beaker with liquid AA standards using middle of range concentration
duplicate sample
duplicate sample
add 3 ml. conc. HNO_3, cover with watch glass
add 3 ml. conc. HCl, cover with watch glass
follow procedures established for preliminary tests [13]
follow procedures established for preliminary tests [13]
store resulting solutions in stoppered bottles for analyses
store resulting solutions in stoppered bottles for analyses

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.4 Preparation of Solutions for Component Recoveries From Filters


25 ml. of distilled H_2O in 4 separate 250 ml. Griffin beakers
spike each beaker with liquid AA standards using middle of range concentration
duplicate sample
duplicate sample
add 3 ml. conc. HNO_3, cover with watch glass
add 3 ml. conc. HCl, cover with watch glass
follow procedure established for preliminary tests [13]
follow procedure established for preliminary tests [13]
store resulting solutions in stoppered bottles for analyses
store resulting solutions in stoppered bottles for analyses

Storage Bottles Polyethylene with Polyethylene Caps

Figure 4.5 Preparation of Solutions for Component Recoveries From Solutions

$$\text{Detection Limit (mg/L)} = 2 \times \frac{\text{standard deviation (absorbance units)}}{\text{mean of 10 runs (absorbance units)}} \times \text{standard concentration (mg/L)}$$

Calibration curves were prepared by running all standards except the lowest ones twice each. Analyses of samples, blanks and recoveries were followed by running of the standards twice if less than 10 samples were being handled. Standards were checked every 10 samples when large numbers of samples were being processed.

Figure 4.6 illustrates the procedures adopted for atomic absorption spectrometric determination of the trace metals under consideration.

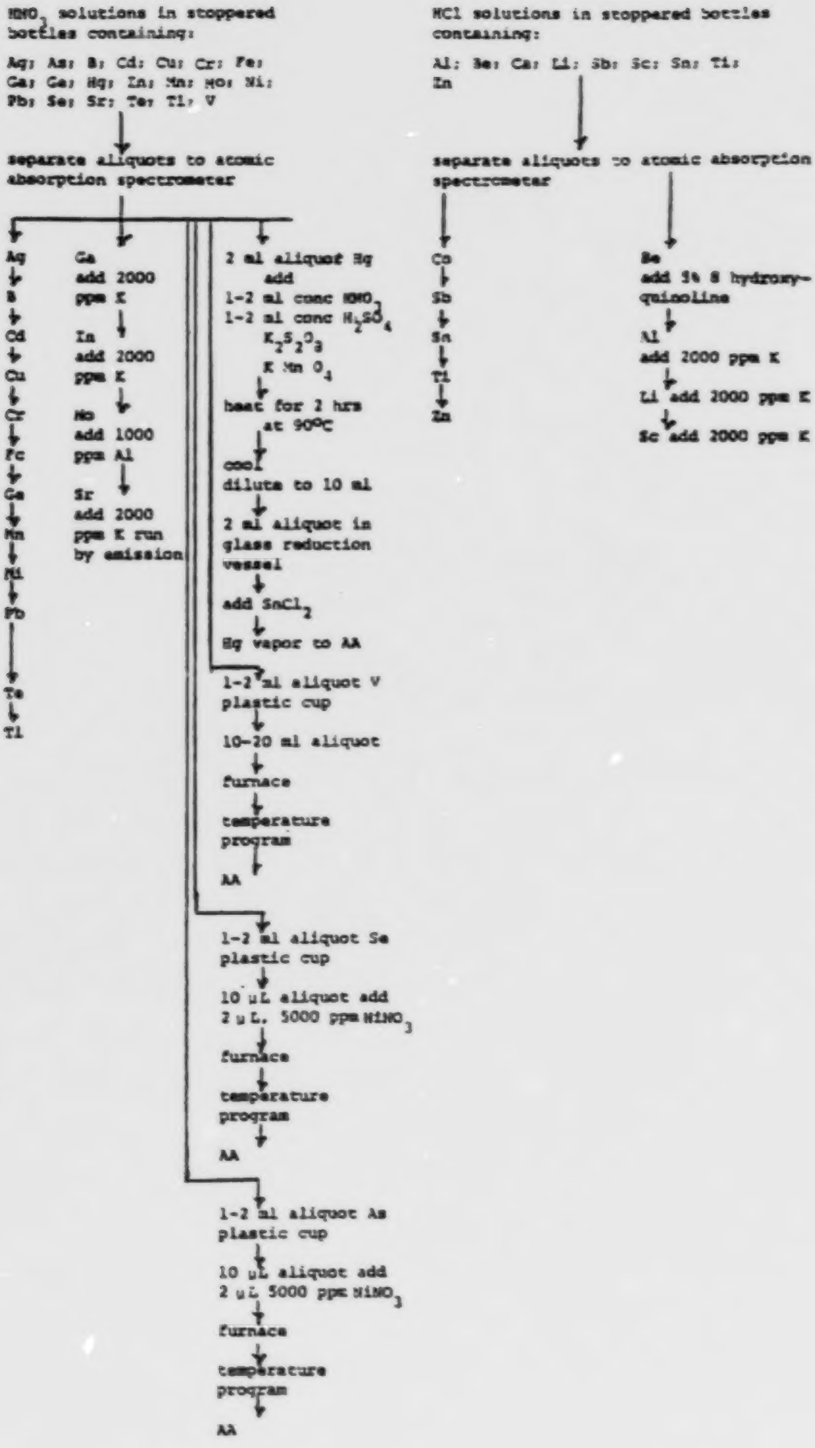

HNO3 solutions in stoppered bottles containing:
Ag; As; B; Cd; Cu; Cr; Fe; Ga; Ge; Hg; In; Mn; Mo; Ni; Pb; Se; Sr; Te; Tl; V
separate aliquots to atomic absorption spectrometer
Ag
B
Cd
Cu
Cr
Fe
Ge
Mn
Ni
Pb
Te
Tl
Ga
add 2000 ppm K
In
add 2000 ppm K
Mo
add 1000 ppm Al
Sr
add 2000 ppm K run by emission
2 ml aliquot Hg
add
1-2 ml conc HNO3
1-2 ml conc H2SO4
K2S2O8
K Mn O4
heat for 2 hrs at 90°C
cool
dilute to 10 ml
2 ml aliquot in glass reduction vessel
add SnCl2
Hg vapor to AA
1-2 ml aliquot V
plastic cup
10-20 ml aliquot
furnace
temperature program
AA
1-2 ml aliquot Se
plastic cup
10 µL aliquot add 2 µL 5000 ppm NiNO3
furnace
temperature program
AA
1-2 ml aliquot As
plastic cup
10 µL aliquot add 2 µL 5000 ppm NiNO3
furnace
temperature program
AA
HCl solutions in stoppered bottles containing:
Al; Be; Ca; Li; Sb; Sc; Sn; Ti; Zn
separate aliquots to atomic absorption spectrometer
Ca
Sb
Sn
Ti
Zn
Be
add 5% 8 hydroxy-quinoline
Al
add 2000 ppm K
Li add 2000 ppm K
Sc add 2000 ppm K

Figure 4.6 Treatment of HNO_3 and HCl Solutions for Atomic Absorption Spectrometry

V. RESULTS

Comprehensive pre-sampling investigations indicated that meaningful results could only be obtained with pre-concentration of field blanks and liquids recovered from impingers and cold traps.

A. DEVELOPMENT

1. Pre-Test Program

Inductively Coupled Argon Plasma analysis of the distilled water samples showed no significant differences in quality with respect to metal content. No element exceeded the instrumental detection limits with the exception of silver (Ag) which was detected in the ERCB demineralized and University of Calgary normally distilled waters. The demineralized water from the ERCB laboratory in Edmonton, Alberta was selected because quality control could be more readily maintained throughout this study. The preparation of the demineralized water is described in Appendix II.

Analysis of two blank samples of the Baker Instra-Analyzed nitric acid that was to be used during this investigation identified the presence of arsenic (As), boron (B), beryllium (Be), cadmium (Cd), copper (Cu) molybdenum (Mo), nickel (Ni), antimony (Sb), selenium (Se), and tin (Sn). Table 5.1 shows that most of these metals were measured at levels of 1 to 2 times their detection limits. The manufacturer's lot analysis of the nitric acid is provided in Appendix II.

Table 5.2 summarizes the results of the ICAP analyses of nitric and hydrochloric acid solutions derived from the leaching of filter materials. On the basis of these data, the quartz micro fibre medium was selected for test purposes after Mr. Larry West(31) volunteered to provide 100 circles cut to 125 mm diameter requirements. Normally quartz microfibre filters are available in 8 x 10 inch sheets and circles of 55 mm diameter.

Table 5.3 provides a summary of the ICAP analysis of the 6M $HN0_3$ solutions used to wash the nozzle and probe liner, the three ice-bath impingers, the two cold trap impingers and connecting glassware.

2. Preliminary Field Testing

The analytical procedures were finalized following field experiences with standard borosilicate glass fibre filters and solutions from the preliminary test at the Ram River Gas Plant(13).

Element

Blank Sample	As	B	Be	Cd	Cu
	Concentration in ppm				
1	< 0.125	0.015	0.002	< 0.010	< 0.010
2	0.204	< 0.013	< 0.001	0.013	0.015
Detection Limit	0.125	0.013	0.001	0.010	0.010
	Mo	Ni	Sb	Se	Sn
1	0.030	< 0.020	0.112*	< 0.300	< 0.150
2	0.047	0.056	1.864*	0.411	0.318
Detection Limit	0.025	0.020	*.***	0.300	0.150

* ICAP Interferences

Table 5.1: Summary of ICAP Analyses of Baker Instra-Analyzed Nitric Acid Blanks

Filter

Element	125 mm Borosilicate		125 mm micro-quartz		8 x 10 inch micro-quartz	
	HNO_3	HCl	HNO_3	HCl	HNO_3	HCl
Ag Silver	VL VL	- -	L L	VL VL	VL	-
Al Aluminum	H H	VH VH	VL VL	L L	H	VH
As Arsenic	L L	- -	- L	VL -	-	L
B Boron	H L	VH VH	L L	L VL	L	H
Be Beryllium	- -	- -	- -	- -	-	-
Cd Cadmium	- -	- -	VL -	- -	-	-
Co Cobalt	- -	- -	- -	- -	-	-
Cu Copper	VL VL	VL VL	VL -	VL VL	VL	VL
Fe Iron	L L	H H	VL VL	L L	L	L
Ga Gallium	- -	- -	- -	- -	-	-
Ge Germanium	- -	- -	- -	- -	-	-
Hg Mercury	L -	- L	- -	- -	-	-
In Indium	- -	- -	- -	- -	-	-
Li Lithium	- -	VL VL	- -	- -	-	-
Mn Manganese	VL -	VL VL	- -	- -	VL	VL
Mo Molybdenum	VL -	- -	- -	- -	-	-
Ni Nickel	VL VL	VL VL	VL VL	- VL	-	-
Pb Lead	- -	- -	- -	- -	-	-
Sb Antimony	- -	H H	- L	- -	-	L
Sc Scandium	- -	VL VL	- -	- -	-	-
Se Selenium	- -	VL -	- -	- -	-	-
Sn Tin	- -	VL VL	- -	- -	-	-
Sr Strontium	- -	VL VL	- -	- -	-	-
Te Tellurium	- -	VL -	- -	- -	-	-
Ti Titanium	L L	L H	- -	- -	VL	VL
Tl Thallium	- -	L -	- -	- -	-	-
V Vanadium	- -	VL VL	- -	- -	-	-
Zn Zinc	VL -	VL VL	VL VL	VL VL	VL	L

VL < 0.05 ppm L = 0.05 - 1 ppm

H = 1 - 10 ppm VH > 10 ppm

- = not detected

Table 5.2 Comparison of Filter Qualities on the Basis of Inductively Coupled Argon Plasma Spectrometry

Element	Sampling Train Component						
	Probe and Nozzle (Washes)	Filter (Leaching)	Impingers (Washes)			Glass Connectors (Washes)	
			1	2 & 3	4 & 5	1	2
Ag Silver	-	-	-	-	-	-	-
Al Aluminum	-	-	-	-	-	-	-
As Arsenic	L	-	L	L	-	L	L
B Boron	VL	-	-	-	-	-	-
Be Beryllium	-	VL	-	-	-	-	-
Cd Cadmium	-	-	-	-	-	-	-
Co Cobalt	-	-	L	-	-	-	L
Cu Copper	L	VL	VL	-	-	L	-
Fe Iron	L	VL	VL	VL	VL	L	-
Ga Gallium	-	-	-	-	-	-	-
Ge Germanium	-	-	-	-	-	-	-
Hg Mercury	L	-	L	-	VL	-	-
In Indium	-	-	-	-	-	-	-
Li Lithium	-	-	-	-	-	-	-
Mn Manganese	-	-	-	-	-	-	-
Mo Molybdenum	VL	VL	VL	VL	-	-	VL
Ni Nickel	L	L	L	L	-	L	L
Pb Lead	-	-	-	-	-	L	-
Sb Antimony	H*	H*	H*	H*	H*	H*	H*
Sc Scandium	-	-	-	-	-	-	-
Se Selenium	L	L	L	-	L	-	L
Sn Tin	L	L	L	L	L	L	L
Sr Strontium	-	-	-	-	-	-	-
Te Tellurium	-	-	-	L	-	-	-
Ti Titanium	-	-	-	VL	-	-	-
Tl Thallium	L	L	L	L	-	L	L
V Vanadium	-	-	-	-	-	-	-
Zn Zinc	VL	-	-	-	-	-	-

VL < 0.05 pp

L = 0.05 - 1 ppm

H = 1 - 10 ppm

VH > 10 ppm

- = not detected

* see Table 5.1

Table 5.3 Summary of Metal Levels in Probe, Filter and Impinger Washes as Determined by Inductively Coupled Argon Plasma Analyses

B. PLANT TESTS

Eight particulate matter sampling tests (1 preliminary and 7 official) were conducted at the Shell Canada Resources Limited - Waterton Gas Plant between September 4-8, 1982 and October 6-8, 1982. A 316-stainless steel probe liner was employed in three tests in order to assess the degree of sample contamination due to leaching of trace elements during sample recovery with water and nitric acid washes. Borosilicate glass liners longer than 12 feet are easily broken at elevated temperatures (greater than 500°F) due to differential stressing when mating the stainless steel nozzle to the glass liner or during handling. The use of stainless steel liners would eliminate the frequent and lengthy onsite delays associated with glass liner replacement.

All four tests at the Gulf Oil Canada Limited-Pincher Creek Gas Plant were performed with a glass lined probe during the October 9-11, 1982 period.

Appendix IV details the field data, isokineticity checks, individual metal concentrations and emission rates for the 12 source sampling tests.

Appendix V provides the sour gas plant operating data collected during the actual testing periods.

Tables 5.4 and 5.5 summarize the laboratory recoveries of the 29 metals from spiked filter and liquid samples.

The trace element emission rates of metals whose presence was "detected", are summarized in Figures 5.1, 5.2, and 5.3. These values were determined employing the measured elemental concentrations and values corresponding to the limits of detection (LOD) for the four samples recovered from the sampling train for each test. Consequently, the mean emission rates corresponding to the full circles represent maximum possible values. The upper and lower bounds indicate the range of emission rates for each plant tested. Open circles indicate the average of the maximum emission rates which correspond to the use of LOD values only.

Discussions following the 65th Canadian Chemical Conference(32) and peer reviews(33-36) indicated the necessity for carefully defining criteria used to "establish" the presence of any metal in the incinerator stack gases at significant levels because of the sporadic appearances and low concentrations associated with the elements.

A metal is reported as being present in significant amounts if the element was "detected"

i) in more than one-half of the tests or

ii) at a concentration 3 times the limit of detection (LOD).

Table 5.6 summarizes the plant emission rates using these criteria.

ELEMENT	WATERTON				PINCHER CREEK		AVERAGE
	Tests Prelim, 1,2,4		Tests 3,5,6,7		Tests Prelim, 1,2		
	Recovery %		Recovery %		Recovery %		
Ag Silver	48*	85*	10*	11*	105**	110**	62±45
Al Aluminum	100	100	60	68	83	85	83±16
As Arsenic	78	150	160	160	160	160	145±33
B Boron	55	75	94	107	97	90	86±19
Be Beryllium	80	84	72	80	100	100	86±12
Cd Cadmium	88	96	88	88	96	96	92±4
Co Cobalt	120	115	75	85	85	83	94±19
Cu Copper	105	105	90	95	100	100	99±6
Cr Chromium	ns	ns	ns	ns	85	85	85
Fe Iron	100	95	100	100	115	115	104±9
Ga Gallium	95	100	88	87	115	115	100±13
Ge Germanium	95	90	85	90	90	90	90±3
Hg Mercury	90	96	100	93	92	92	94±4
In Indium	95	95	92	85	97	105	95±7
Li Lithium	108	104	68	76	92	92	90±16
Mn Manganese	104	110	64	76	70	64	81±20
Mo Molybdenum	90	90	93	95	93	93	92±2
Ni Nickel	105	105	96	87	100	100	99±7
Pb Lead	90	100	85	80	100	100	93±9
Sb Antimony	104	86	89	88	87	92	91±7
Sc Scandium	63	70	58	66	80	80	70±9
Se Selenium	100	110	-	120	-	-	110±10
Sn Tin	104	86	83	93	90	85	90±8
Sr Strontium	94	92	100	100	110	110	101±8
Te Tellurium	98	94	87	88	88	90	91±4
Ti Titanium	80	85	53	58	83	81	73±14
Tl Thallium	83	83	74	77	110	110	90±16
V Vanadium	125	120	100	95	125	135	117±16
Zn Zinc	72	76	99	121	108	112	98±20

*apparent standard contamination with chloride

**new standard used

Table 5.4 Laboratory Recoveries of Spiked Filters

ELEMENT	WATERTON				PINCHER CREEK		AVERAGE
	Tests Prelim 1,2,4		Tests 3,5,6,7		Tests Prelim,1,2		
	Recovery %		Recovery %		Recovery %		
Ag Silver	72**	60**	10**	37**	105***	110***	66±39
Al Aluminum	95	95	83	78	88	93	89±7
As Arsenic	140	135	120	130	160	160	141±16
B Boron	92	95	100	101	97	90	96±4
Be Beryllium	100	104	112	100	120	120	109±9
Cd Cadmium	102	102	112	108	96	96	103±6
Co Cobalt	103	113	100	95	100	100	102±6
Cu Copper	112	108	95	110	100	100	104±7
Cr Chromium	ns	ns	ns	ns	85	85	85±0
Fe Iron	92	86	111	111	115	115	105±13
Ga Gallium	110	110	100	100	115	115	108±7
Ge Germanium	26	50	100	22	90	90	63±35
Hg Mercury	115	110	10*	10*	92	92	102±12
In Indium	95	95	96	99	97	105	98±4
Li Lithium	112	112	100	96	120	120	110±10
Mn Manganese	108	100	88	88	70	64	86±17
Mo Molybdenum	90	90	100	100	93	93	94±5
Ni Nickel	108	104	99	100	100	100	102±3
Pb Lead	98	98	110	110	100	100	103±6
Sb Antimony	108	114	125	123	110	99	113±10
Sc Scandium	82	82	83	81	95	95	86±7
Se Selenium	52	52	124	120	-	-	87±40
Sn Tin	110	120	110	110	110	110	112±4
Sr Strontium	94	94	110	110	110	110	105±8
Te Tellurium	94	92	99	100	88	90	94±5
Ti Titanium	78	80	85	85	120	120	95±20
Tl Thallium	92	92	88	85	110	110	96±11
V Vanadium	47	37	95	165	125	135	101±51
Zn Zinc	110	110	110	148	130	130	123±16

ns = not spiked
* = spiked low
**apparent standard contamination with chloride
***new standard used

Table 5.5 Laboratory Recoveries of Spiked Liquids

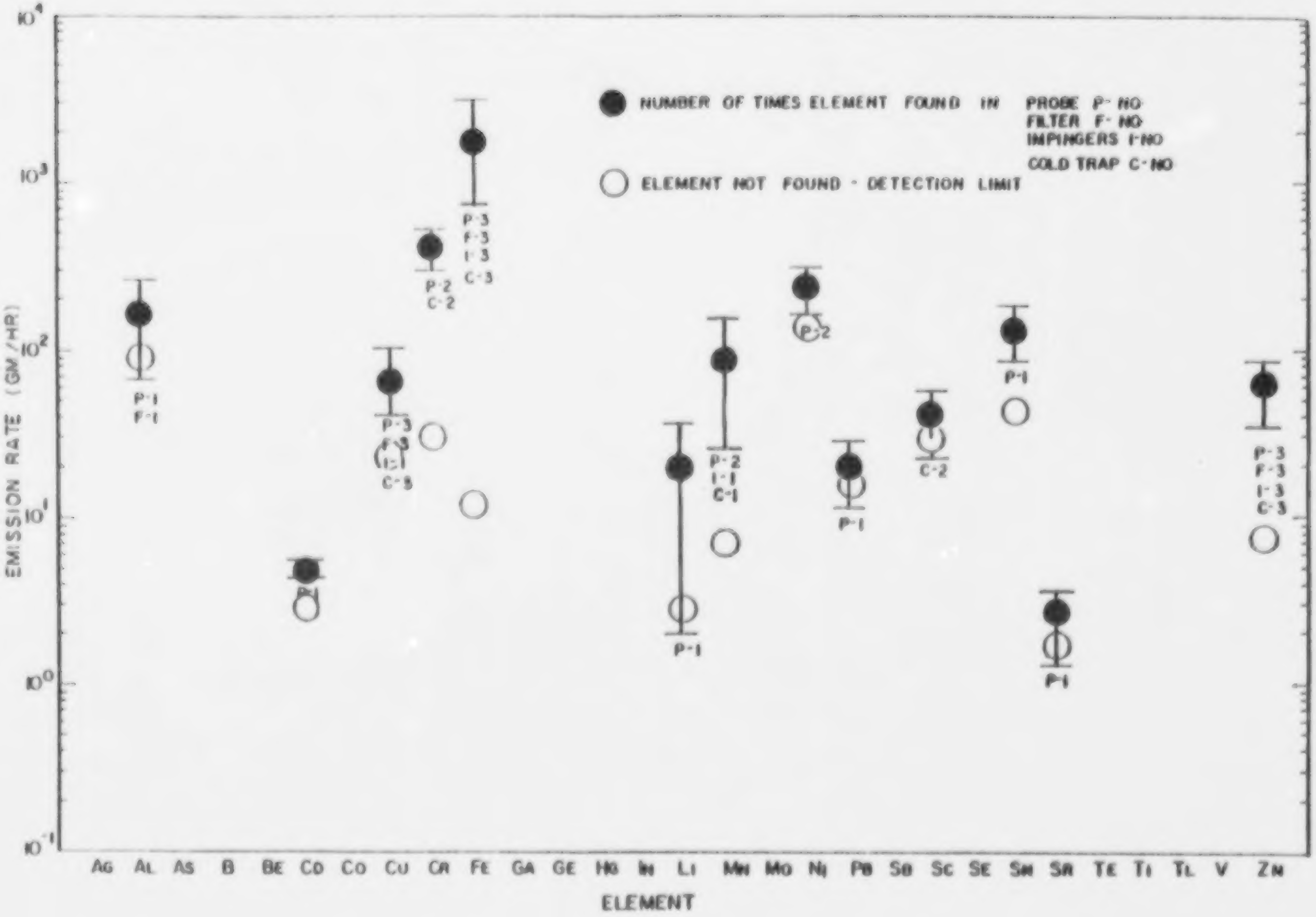


Figure 5.1 Maximum Emission Rates of Metals Whose Presence was "Detected" in Shell-Waterton Incinerator Stack Gases Using a Stainless Steel Liner

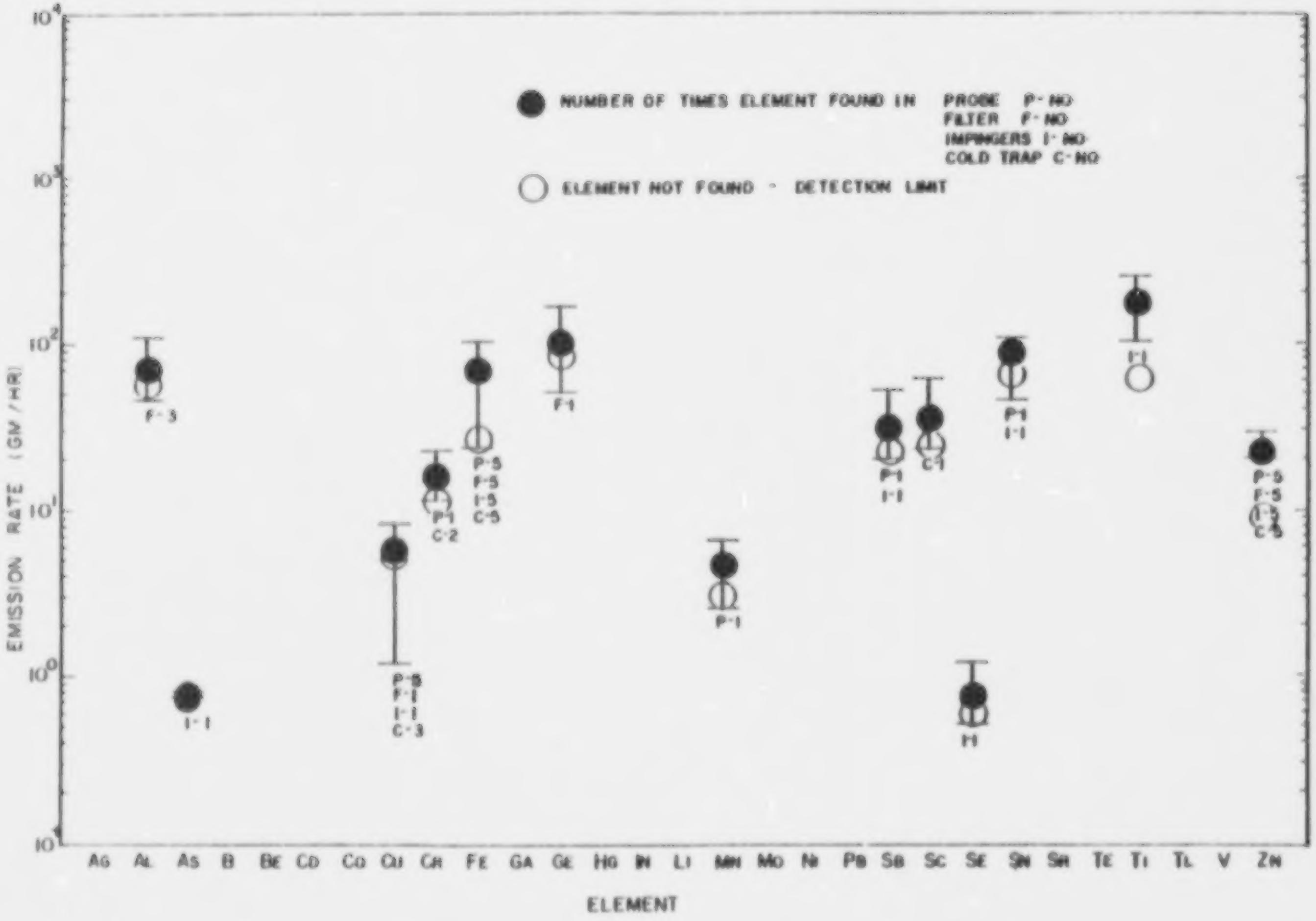


Figure 5.2 Maximum Emission Rates of Metals Whose Presence was "Detected" in Shell-Waterton Incinerator Stack Gases Using a Borosilicate Glass Liner

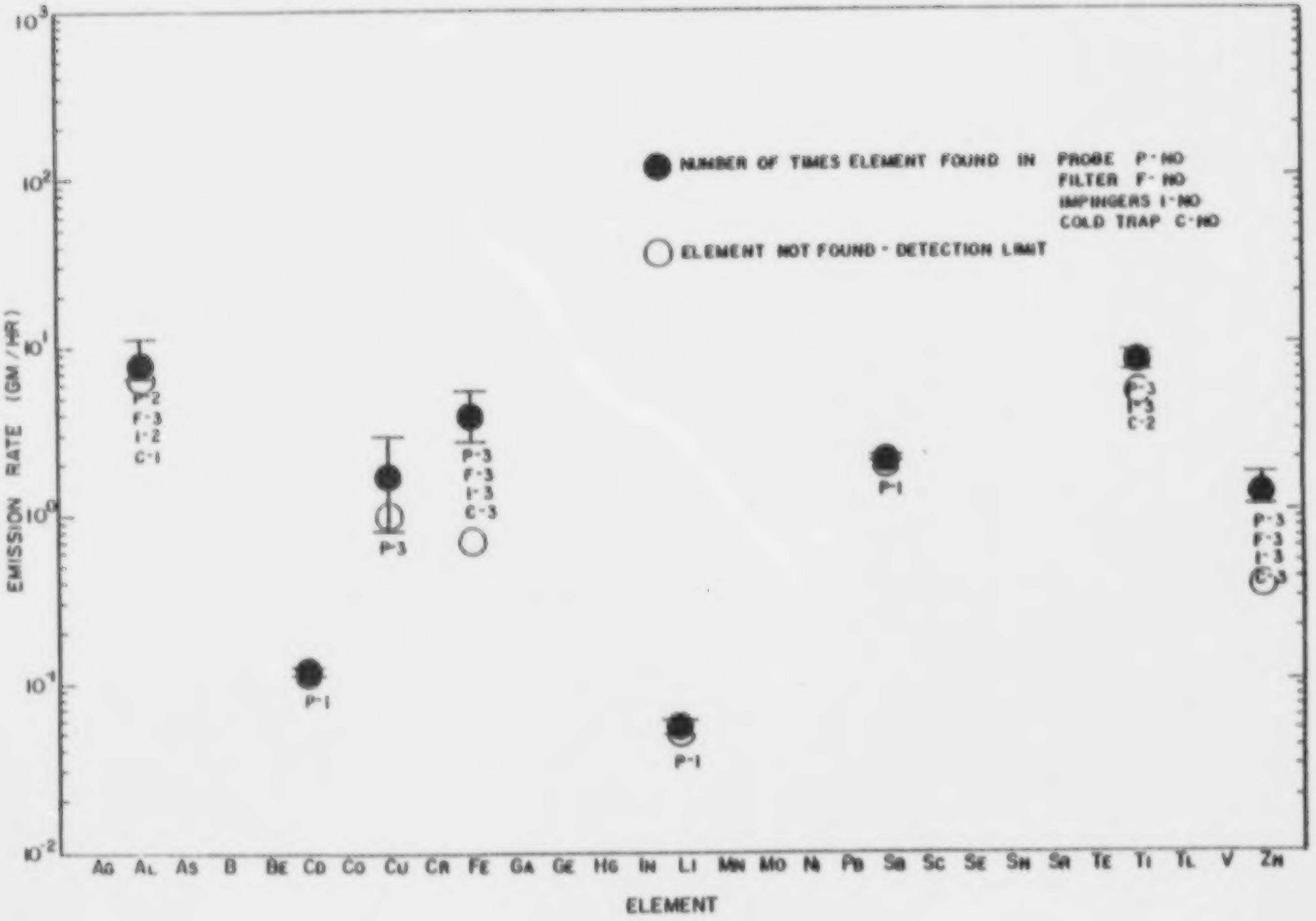


Figure 5.3 Maximum Emission Rates of Metals Whose Presence was "Detected" in Gulf-Pincher Creek Incinerator Stack Gases Using a Borosilicate Glass Liner

Plant Test	Date D/M/Y	Liner	Plant Production $10^6 m^3/d$	Average Stack Temperature T_s (°F)	Average Moisture by Condensation B_{wo}	Average Stack Velocity U_s ft/s	Average Volumetric Flowrate Q_s acfm	Average SO_2 Concentration % by Volume	Metal Species Emission Rate g/h Al	Cu	Cr	Fe	Mn	Ni	Sn	Ti	Zn	Emission Rate Front End 10^3 kg/d	Total 10^4 kg/d
Shell Waterton Preliminary	4/9/82	G	2.56	873	0.081	61.5	663000	0.04	-	8.1	19	100	6.8	-	100	-	28	1.5	*2.6
#1	5/9/82	SS	2.61	875	0.104	61.1	659000	0.04	360	100	530	1000	140	110	-	-	89	9.8	*0.17
#2	6/9/82	SS	2.61	870	0.088	61.4	662000	0.04	-	28	150	770	36	110	66	-	33	3.5	*2.0
#3	7/9/82	SS	2.53	870	0.088	61.4	662000	0.04	25°	4.1°	-	18°	2.1°	-	-	-	11°	1.5°	*2.3
#4	8/9/82	G	2.73	871	0.106	64.7	698000	0.04	-	17	15	78	-	-	-	-	20	3.5	*3.6
#5	6/10/82	G	2.32	835	0.095	54.7	589000	0.04	110°°	1.2°°	-	24°°	-	-	-	-	21°°	1.0°°	*2.2°°
#6	7/10/82	G	2.30	839	0.096	57.5	619000	0.04	46	7.3	-	73	-	-	91	140	21	1.8	*1.9
#7	8/10/82	G	2.56	839	0.105	57.8	623000	0.04	52	6.4	-	79	-	-	-	-	20	2.3	*2.2
Gulf Pincher Creek Preliminary	9/10/82	G	0.40	1160	0.115	60	50,900	0.28	6.5	2.9	-	2.7	-	-	-	6.9	1.7	0.2	*0.7
#1	10/10/82	G	0.41	1160	0.105	59	50,600	0.51	11	1.3	-	5.4	-	-	-	9.1	1.2	0.2	*1.1
#2	10/10/82	G	0.39	1160	0.128	59	49,900	0.40	6.7	0.8	-	3.2	-	-	-	7.9	1.1	0.2	*0.1
#3	11/10/82	G	0.39	1160	0.044	57	48,000	0.38	-	samples not analysed									

°probe and nozzle sample bottle broken in transit; not used for averaging

°°part of probe and nozzle wash lost during analysis; data used for averaging

G = Glass Liner   S.S. = Stainless Steel Liner

*Impinger contents could not be evaporated to dryness at temperature specified by Alberta Stack Sampling Code

Table 5.6 Summary of Emission Rates of Elements Whose Presence Was Established At Shell-Waterton and Gulf-Pincher Creek Gas Plants Using Stainless Steel or Borosilicate Glass Lined Probes

Appendix VI details the maximum possible incinerator stack emission rates that could exist without detection of any metallic species employing the sample recovery and analytical procedures developed for this investigation. The effects of preconcentration, total gas sample volume collected and instrumental limits of detection on the maximum possible rates are discussed in detail.

VI. DISCUSSION OF RESULTS

A. SHELL-WATERTON

1. Stainless Steel Liner

Although the use of stainless steel liners would eliminate delays caused by the breakage of borosilicate glass tubes, examination of Table 5.6 and Figures 5.1 and 5.2 shows that significant sample bias occurs when a new metal liner is used. Table 6.1 illustrates the overestimation of elemental emissions when rates are calculated on the basis of sample recovery from stainless steel lined probes.

	Average Emission Rates (g/h)		% Increase
Metal	ER_{SS}, Stainless Steel Actual 2 Tests	ER_g, Glass Actual 5 Tests	$\frac{(ER_{ss} - ER_g)\ 100}{ER_g}$
Aluminum	160	70	130
Copper	64	8	700
Chromium	340	16	2030
Iron	1890	71	2560
Manganese	83	5	1560
Nickel	210	Not detected	
Zinc	61	22	180

Table 6.1 Comparison of Elemental Emission Rates Based on Sample Recovery From Stainless Steel and Borosilicate Glass Lined Probes at Shell-Waterton Gas Plant.

The significant increases in the emission rates for iron, chromium, and nickel shown in Table 6.1 can be related to the major components of the 316 stainless steel liner. However, a critical examination of the data in Table 5.6 shows that aluminum, copper, chromium, iron, manganese, nickel and zinc exhibited decreasing emission rates for successive tests with the steel liner. It would appear that leaching of these elements from a new surface occurs for a limited time period. Due to breakage of the bottle containing the probe and nozzle washes for Test 3, it is not possible to determine if surface conditioning of the stainless steel liner was sufficient to have emission rates approach those determined with a glass liner.

2. Glass Liner

The presence of aluminum, copper, iron, tin, titanium and zinc was established in the incinerator stack gases at the Waterton plant. Discussions with operators after the public peer review(37) suggested that no copper equipment, lines or valves are used in sour gas plants. The presence of copper in the stack gases due to plant construction materials cannot be explained until the inplant sampling study(38) is completed. On the basis of the presently available evidence it must be concluded that copper may be introduced into the system with the entering raw sour gas stream.

Significant proportions of the aluminum, iron, titanium and zinc found in the stack gases may be evidence of equipment deterioration as a result of normal corrosion and erosion. Potential in-plant sources of aluminum are refractory linings and the alumina sulfur conversion catalyst used in the Claus process. Titanium might also be a component of refractory linings. The presence of zinc is more difficult to explain at this time. It is possible that zinc anodes used in corrosion control contaminate process streams and/or zinc enters the plant in the raw gas feed stream.

The sporadic detection of arsenic (1 out of 5 tests), chromium (2 out of 5), germanium (1 out of 5), manganese (1 out of 5). antimony (2 out of 5), scandium (1 out of 5), and selenium (1 out of 5), at levels just above the detection limits (as shown in Figure 5.2) indicates that these elements are released into the atmosphere at trace concentration levels. This behaviour suggests that conditions in the plant were not steady throughout the tests.

B. GULF-PINCHER CREEK

Aluminum, copper, iron, titaniun and zinc were consistently present in the gases exhausted from the incinerator stack at levels significantly above the detection limits. The source of the copper may be established after the completion of the flare stack study (38). This investigation could also help to explain the consistent appearance of titanium. The identification of cadmium (1 out of 3), lithium (1 out of 3) and antimony (1 out of 3) at levels just above detection limits suggests these metals are released into the atmosphere at trace concentration levels. Intermittent emissions of trace elements could be indicative of unsteady state operations in the plant.

C. TOTAL PARTICULATE MATTER EMISSIONS

A source test conducted to determine particulate matter emission rates shall include two emission values:(11)

1) The first emission rate based on the amount of particular catch in the front-half of the train (in nozzle, probe and filter); and

2) the second emission rate which is based on the total of filtered material in item (1) above plus any particulate matter collected in the impinger solutions.

An examination of Table 5.6 shows that the sums of all the pure metal emissions constitute 1.5 to 4.2% of the samplng train front-half emission rates when a glass liner is used. For stainless steel liners this ratio ranges from 11 to 39%.

It is not surprising that the pure metals constitute such a small fraction of the front-half emission rate since they are probably emitted in their oxide, sulfate or in part as silicate forms whose formula weights are approximately 2 to 4 times higher than those of the pure metals. In addition, accounting for the presence of silicon (Si), calcium (Ca), potassium (K), sodium (Na), and magnesium (Mg) in stack emissions would significantly improve the agreement between the elemental and front-half emission rates.

A reliable estimate of the total particulate catch in the impinger solutions could not be made since these liquids could not be evaporated to dryness at 100 °C as prescribed by AERM(11). Instead of a dry residue, an oily liquid, probably sulfuric acid, remained no matter how long drying was carried out at 100 °C. The sulfuric acid was generated when sulfur dioxide (SO_2) was absorbed by the 6M nitric acid impinger solutions. In addition, some sulfuric acid may arise from trace emissions of SO_3 from the Claus Units. It was impossible to define a constant final weight since sample weights increased during the weighing process as water from the ambient air was absorbed. Consequently, the total emission rate is grossly overestimated following the specified procedures(11).

D. COMPARISON OF PLANT OPERATIONS

Sulfur dioxide concentrations in the Pincher Creek Plant stack gases are ten times higher than those measured at the Waterton Plant (0.40 ± 0.10 versus 0.04 percent). The low levels at the Waterton Plant are achieved by processing the gas streams leaving the Claus Sulfur Units in the catalytic Shell Claus Off-Gas Treating (SCOT) Unit which is designed to provide a 98.7% overall recovery of sulfur from the original raw gas stream. Table 6.2 shows that the concentrations of the metals whose presence has been definitely established in the Waterton and Pincher Creek Gas Plant incinerator stack gases are of the same order of magnitude.

The emission rates of the metals exhausted from the two incinerator stacks are proportional to the volumetric gas flow rates.

	Pincher Creek Volumetric Flowrate 50,000±900 acfm*		Waterton Volumetric Flowrate 647,000±34,000 acfm	
	Average Concentration ug/rcf**	Average Emission Rate g/h	Average Concentration ug/rcf	Average Emission Rate g/h
	(Arithmetic Means with standard deviations)			
Aluminum	9.9±3.5	8.1±2.5	5.6±3.0	69±35
Copper	1.9±1.4	1.7±1.1	0.8±0.3	8.0±5.7
Iron	4.6±1.8	3.8±1.4	5.5±2.1	71±28
Titanium	9.6±1.4	8.0±1.1	11.0	186
Zinc	1.6±0.4	1.3±0.3	1.7±0.2	22±3

Table 6.2 Comparison of Average Concentrations and Emission Rates of Metals Found in the Pincher Creek and Waterton Gas Plant Incinerator Stacks.

* acfm = Actual cubic feet per minute at stack temperature and pressure.

**rcf = Reference cubic feet at 25 °C, 1 atm.

E. RANDOM ERROR ANALYSIS

At the conclusion of the entire trace element emission study a comprehensive error analysis will be developed to establish the random error limits on the total and elemental emission rates due to:

i. equipment and personnel variations in field procedures

ii. equipment and personnel variations in the laboratory.

VII. CONCLUSIONS AND RECOMMENDATIONS

The presence of aluminum, copper, iron, tin, titanium and zinc has been established in the incinerator stack gas emissions from the Shell-Waterton Gas Plant.

Aluminum, copper, iron, titanium and zinc were consistently present in the gases exhausted from the Gulf-Pincher Creek Gas Plant incinerator stack.

The nature and amounts of the elements released to the atmosphere would not appear to create a critical emission problem in the Pincher Creek area. The impact of the incinerator stack emissions on downwind, ambient, ground level concentrations is expected to be negligible. Preliminary estimates made in response to questions generated during the 66th Canadian Chemical Conference(32) indicate that the predicted impact of the Shell-Waterton incinerator stack emissions on downwind ambient concentrations would be minimal. On the basis of ambient sampling carried out at the inlet to the incinerator of the Shell-Waterton Gas Plant, incinerator stack emissions are projected to contribute less than 2% of the aluminum, copper, iron and zinc background in the air at downwind locations where maximum deposition is likely to occur. Identifiable levels of tin and titanium at concentrations of 0.0037 and 0.0077 ug/m^3, respectively, have been predicted for downwind locations, although these metals were not detected at the incinerator inlet.

Short-range atmospheric dispersion modelling of the emissions from both plants is recommended to more accurately assess the impact on receptors at ground level.

Further testing with a stainless steel liner should be conducted to determine if sufficient surface conditioning can be achieved to yield emission rates consistent with those determined with a glass liner.

The various sources of the trace elements emitted from the incinerator stacks are expected to be identified by the flare stack study(38).

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APPENDIX I

GAS CHROMATOGRAPH CALIBRATION GAS ANALYSIS
and
TECHNICAL DATA ON ULTRA-PURE QM-A QUARTZ FILTERS

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Our File: 11Y-24-82

Energy Resources Conservation Board
640 - Fifth Avenue S.W.
Calgary, Alberta
T2P 3G4

Attention: Dr. H. Thimm

Dear Dr. Thimm,

Re: Analysis of Gas Sample

G.L. Standard

This concerns the analysis of a gas sample picked up from your office in Calgary on October 8th, 1982.

The sample was reported to contain approximately:

	Mole Fraction
N_2	0.945
CO	0.015
CO_2	0.040

Accordingly, a sample of gas containing these materials was prepared by charging known amounts of the pure components into a high pressure sample bomb and obtaining the weights of each component gravimetrically using a Mettler balance having a resolution of 0.0001 g. The composition of this sample was:

	Mole Fraction
N_2	0.8978
CO	0.0158
CO_2	0.0864

Relative response factors for each of the components in the mixture were determined from this primary standard.

The unknown sample was then analyzed using a molecular sieve 5A 60-80 mesh column using temperature programming from 35 to 170°C. During these operations it was determined that the "nitrogen" in the sample was actually air, and additional work had to be done to clarify this problem. The composition of the mixture was calculated to be:

Component	Concentration Mole Fraction	Reliability
O_2	0.1987	±0.0001
N_2	0.7474	±0.0005
CO	0.0141	±0.0001
CO_2	0.0398	±0.0002

If you have any questions about the results, please give us a call. It was a pleasure to be of assistance to you.

Yours very truly,

DB ROBINSON & ASSOCIATES LTD.

D. B. ROBINSON

PRESIDENT

DBR/plr

Whatman PAPER DIVISION

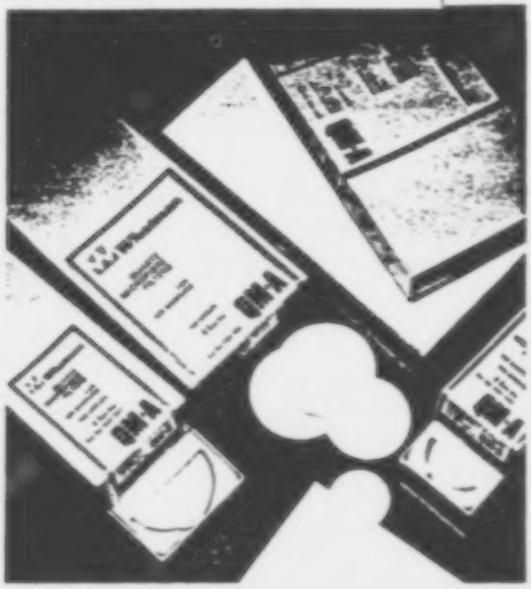
LARRY G. WEST
Technical Services Specialist

Whatman Laboratory Products Inc

9 Bridewell Place, Clifton, NJ 07014
201-773-5800 Telex 133426
a member of the Whatman Reeve Angel Group

TECHNICAL DATA ON

ULTRA-PURE QM-A QUARTZ FILTERS



QM-A. THE NEW ULTRA-PURE QUARTZ FILTER FROM WHATMAN FOR AIR SAMPLING.

Whatman now introduce QM-A, an ultra-pure quartz (SiO_2) microfibre filter for the most exacting work in air pollution monitoring. QM-A is heat-treated and entirely binder free and only a small amount (5%) of conventional borosilicate glass microfibres are added for papermaking purposes.

ULTRA-PURE – HIGH FLOW RATES

Ultra-pure QM-A is extremely low in heavy metal content, whilst offering the high flow rates and filtration efficiencies of conventional borosilicate glass microfibre filters. Trace level determinations in particulates can now be carried out with the utmost accuracy.

LOW IN ALKALINE EARTH METALS

Whatman QM-A contains virtually no alkaline earth metals and is therefore recommended for sampling and subsequent analysis of environments where acidic gases such as SO_2 and NO_2 are encountered. 'Artifact' production of sulphates and nitrates on the filter, is, thus, virtually eliminated with QM-A and critical analyses can now be conducted free from inaccuracies caused by artifact production with glass microfibre filters.

APPLICATIONS

Whatman QM-A is suitable for ambient and high temperature (max 500° C) air sampling of environments such as stacks, flue outlets and aerosols. Being ultrapure and containing low levels of elements important in pollution studies, Whatman QM-A is the filter of choice for critical analyses and trace level determinations, and it is especially suitable for analytical techniques such as atomic absorption spectroscopy and flame emission spectrophotometry.
The low background levels of heavy metals in QM-A also make it suitable for X-ray fluorescence techniques and neutron activation analyses

MINIMAL WEIGHT LOSS

QM-A is heat treated after manufacture to remove bound moisture and trace organic impurities and to ensure minimal weight loss on further heating. For accurate gravimetric results, as with any medium, it is essential, both before and after sampling, to condition the filter carefully before weighing.

QM-A QUARTZ TECHNICAL DATA

Basis Weight	85 gm/m²
Thickness	0.45 mm
Particle retention efficiency	99.999% retention (0.6 μm particles at 5cm/sec F.V.) or 0.001% penetration
Dry Tensile (1.5 cm wide strip)	250 – 300 g
Maximum Temperature	500° C
Air flow rate	800 litres/min (for 400 cm² filter area at Δ p = 20 mm Hg)

N.B. 400 cm² is effective filtration area of 8'' x 10'' sheet

CHEMICAL PURITY

Element	p.p.m.	Micrograms per sheet (8 x 10 in)
Cd	0.23	1
Co	1.1	5
Cr	1.6	7
Cu	3.4	15
Fe	23.0	100
Mn	0.46	2
Ni	3.4	15
Pb	2.3	10
Zn	18.2	80

All values typical subject to normal manufacturing tolerances.

AVAILABILITY

Standard Sizes		Cat. No.
Circles:	3.2 cm dia	1851 032
	3.7	1851 037
	4.7	1851 047
	5.5	1851 055
Sheets:	20.4 x 25.4 cm (8 x 10 in)	1851 865

PUBLICATION NO 860 QM-A A

QM-A QUARTZ ULTRA-PURE FILTERS DATA SHEET 860 QM-A A

COMPARISON OF PHYSICAL CHARACTERISTICS AND CHEMICAL PURITY OF WHATMAN QM-A QUARTZ MICROFIBRE FILTERS, EPM1000, GF/A AND GRADE 41

(1) PHYSICAL CHARACTERISTICS:

	QM-A	EPM1000	GF/A	No. 41
Composition	Quartz Microfibre	Glass Microfibre	Glass Microfibre	Cellulose (Cotton Linters)
Basis weight	85	80	53	85
Thickness (mm)	0.45	0.43	0.28	0.21
Dry Tensile[a] (g)	250-300	742	430	2400
Sodium Flame Retention[b] (Nefel (%))	99.980	99.990	99.985	74
ΔP[c] (mm Hg)	3	3	3	3
Temperature Resistance (Max. °C)	500	500	500	200
Air[d] Flow Rate at ΔP = 3	120	120	120	120
Air[d] Flow Rate at ΔP = 20	800	750	950	1150

NOTES

[1] All values are 'typical' and subject to normal manufacturing tolerances.

[a] Tensile 1.5 cm wide strip

[b] Sodium flame penetrometer to BS 4400 all values at 5cms/Sec F.V.

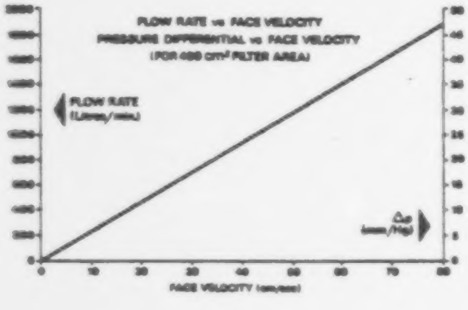
[c] Pressure differential across filter at 5cms/Sec F.V.

[d] Measured in litres/minute for air (values for 400 cm² area assuming no flow restriction imposed by holder)

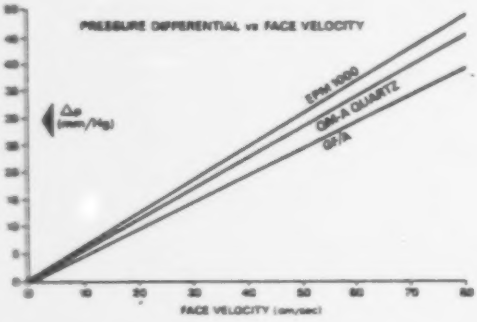
Key F.V. = Face Velocity

NB:ΔP figures at higher FV's than 5 cms/sec vary considerably with grade of filter – see Air Pollution Monitoring brochure for graphs of ΔP vs F.V.

QM-A QUARTZ FILTER FLOW RATE



COMPARISON OF QM-A QUARTZ, EPM1000 AND GF/A



(2) CHEMICAL PURITY Concentrations given in µg/sheet (8'' x 10'') and in p.p.m.

	QM-A		EPM1000		GF/A		GRADE 41	
Element	µg/sheet	p.p.m.	µg/sheet	p.p.m.	µg/sheet	p.p.m.	µg/sheet	p.p.m.
Cd	1	0.23	2.1	0.5	2.7	1.0	ND	ND
Co	4.6	1.1	1.24	0.3	2.7	1.0	ND	ND
Cr	7.0	1.6	4.95	1.2	0.55	0.2	1.3	0.3
Cu	14.9	3.4	2.9	0.7	16.4	6.0	1.75	0.4
Fe	100	23	103	25	275	100	26.3	6.0
Mn	2.0	0.46	4.95	1.2	21.9	8.0	<0.22	< .05
Ni	14.9	3.4	14.4	3.5	16.4	6.0	ND	ND
Pb	10.0	2.3	10.3	2.5	27	10	0.9	0.2
Zn	80	18.2	103	25	ND	ND	2.6	0.6

KEY ND = NOT DETERMINED

NOTES Cellulose Data obtained from analysis of ash. Glass Data obtained from extraction under acid conditions.

Whatman PAPER DIVISION

Whatman Laboratory Products Inc 9 Bridewell Place, Clifton, New Jersey 07014 USA Tel: (201) 773-5800 Sales Tel: (201) 777-4825 Telex: 133426

APPENDIX II

PREPARATION OF DEMINERALIZED WATER
and
ACTUAL LOT ANALYSIS (218042)
for
BAKER INSTRA-ANALYZED NITRIC ACID

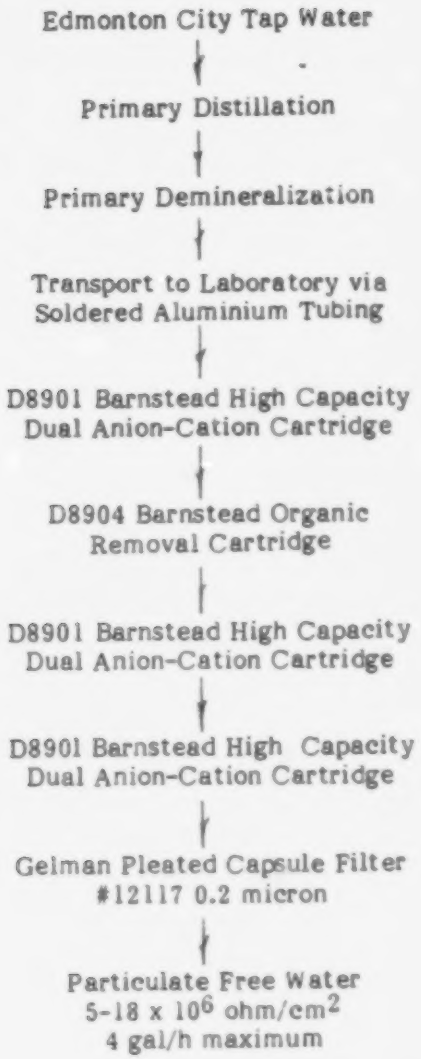

Edmonton City Tap Water
Primary Distillation
Primary Demineralization
Transport to Laboratory via Soldered Aluminium Tubing
D8901 Barnstead High Capacity Dual Anion-Cation Cartridge
D8904 Barnstead Organic Removal Cartridge
D8901 Barnstead High Capacity Dual Anion-Cation Cartridge
D8901 Barnstead High Capacity Dual Anion-Cation Cartridge
Gelman Pleated Capsule Filter #12117 0.2 micron
Particulate Free Water
5-18 x 10^6 ohm/cm^2
4 gal/h maximum

Figure II.1 Preparation of Demineralized Water by Energy Resources Conservation Board Laboratory, Edmonton, Alberta

APPENDIX II

Assay (HNO_3) (by acid base titration)	70.3%
Appearance	Passes test
Color (APHA)	< 5
Density at 20°C	1.426 gm/ml
Residue after ignition	2 ppm

Trace Impurities (ppm) (µg/g)

Chloride (Cl)	< 0.08	Lead (Pb)	0.0002
Phosphate (PO_4)	< 0.1	Lithium (li)	< 0.02
Sulphate (SO_4)	< 0.5	Magnesium (Mg)	0.02
Aluminum (Al)	0.05	Manganese (Mn)	0.0004
Arsenic and Antimony (as As)	< 0.005	Mercury (Hg)	< 0.0001
Barium (Ba)	< 0.02	Nickel (Ni)	0.003
Boron (B)	0.001	Potassium (K)	< 0.1
Cadmium (Cd)	< 0.002	Silicon (Si)	0.01
Calcium (Ca)	0.02	Silver (Ag)	< 0.0001
Chromium (Cr)	0.02	Sodium (Na)	0.2
Cobalt (Co)	0.0002	Strontium (Sr)	< 0.002
Copper (Cu)	0.0003	Tin (Sn)	0.001
Heavy Metals (as Pb)	0.05	Zinc (Zn)	< 0.002
Iron (Fe)	0.02		

Table II.1 Actual Lot Analysis (218042) for Baker Instra-Analyzed Nitric Acid

APPENDIX III

INDUCTIVELY COUPLED ARGON PLASMA SPECTROMETER SPECIFICATIONS

CP (INDUCTIVELY COUPLED PLASMA SPECTROMETER)

Manufacturer:	Applied Research Laboratories Dearborn, Michigan
Model No.	35,000

The 35,000 ICP is an automated liquids analysis instrument for either precise quantitative elemental analysis, or for qualitative elemental purposes.

Specifications

Monocromator - Air Version

Czerny Turner Mounting, High Precision Bausch & Lomb Diffraction Grating

Focal Length 1.0 meter

Blazed At 1200 l/mm

Spectral Range 1900 - 8800 Angstroms (1st order)

Dispersion 8 Angstroms/mm

Width of Primary and Secondary Slit 20/um

Unit is Equipped with an Oxidation Gaseous Hydride Module

High Frequency Generator

Connected to ICP stand by a flexible cable

Operating frequency: 27.12 MHz, quartz stabilized

Maximum power: 2.5 kW

Automatic power regulation

Air cooled

A hot-air exhaust for the stand and for the generator

System Controlled Autosampler

Permits automatic introduction of samples and allows efficient operation by eliminating human error. Contributes to reproducibility and general quality of results while freeing the analyst for more productive activity.

Package consists of an automatic sample changer with capacity for up to 24 sample or rinse containers. Integrated into the 35000 work table. With control circuitry and software compatible with ICP-User's programs and ARL Extended Basic.

APPENDIX IV

FIELD SAMPLING DATA
and
ELEMENTAL EMISSION RATES

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: WATERTON

COMPANY: SHELL

2) TEST NO: Prelim DATE: September 4, 1982

3) PRODUCTION: 2.56×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)

STATIC PRESSURE: -2.6 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 15 1/8 (feet)

5) PITOT TUBE COEFFICIENT: 0.9

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: (No Nozzle Used) (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 7.41, O_2 11.25, CO 0.0

SO_2 0.04, N_2 80.34, Ar 0.96

7) NO. OF READINGS: 48

TIME BETWEEN READINGS: 3 min.

TEST POINTS/TRAVERSE: 12

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 137.1 (grams)

WATER CAUGHT BY DRYING AGENTS: 4.7 (grams)

MOISTURE CONTENT, B_{wo}: 0.081

9) MOLECULAR WEIGHT OF GAS:

29.77 DRY BASIS (lb_m/lb mole)

28.81 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 91.53 (acf)

11) AVERAGE STACK VELOCITY: 61.52 (ft/s); AVG. TEMP: 873 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 563000 (acfm)

TABLE IV.1 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)
							PROBE	OVEN	INPINGERS OUTLET	INPINGERS INLET	GAS METER OUT	GAS METER IN	
0	0	855	0.10	33.01	1.00	461.33	400	340	63	61	66	66	3.00
1	3	850	0.13	37.57	1.00	463.28	400	335	50	150	65	65	3.00
1	6	845	0.13	37.49	1.00	465.23	400	330	50	150	65	67	3.20
2	9	860	0.28	55.34	1.00	467.17	400	320	50	155	65	67	3.20
2	12	862	0.27	54.38	1.00	469.09	400	310	50	150	65	68	3.20
3	15	865	0.35	61.99	1.00	471.02	400	310	50	150	68	70	3.20
3	18	865	0.35	61.99	1.00	472.93	400	320	50	155	68	71	3.20
4	21	870	0.38	64.71	1.00	474.82	400	325	52	155	68	71	3.20
4	24	870	0.37	63.86	1.00	476.72	400	322	52	160	70	72	3.20
5	27	865	0.38	64.59	1.00	478.61	400	338	50	155	70	75	3.20
5	30	868	0.40	66.34	1.00	480.50	400	335	50	160	70	75	3.20
6	33	880	0.42	68.29	1.00	482.39	400	335	50	165	70	75	3.20
6	36	865	0.42	67.91	1.00	484.28	400	338	55	170	72	77	3.20
7	39	870	0.42	68.03	1.00	486.16	400	342	52	170	74	78	3.30
7	42	875	0.42	68.16	1.00	488.06	400	345	52	165	74	78	3.30
8	45	870	0.40	66.39	1.00	489.96	400	347	50	165	74	80	3.30
8	48	865	0.40	66.27	1.00	491.84	400	340	50	175	75	80	3.30
9	51	870	0.39	65.56	1.00	493.73	400	330	50	162	75	80	3.20
9	54	870	0.40	66.39	1.00	496.63	400	325	50	162	75	80	3.20
10	57	875	0.40	66.52	1.00	497.53	400	315	50	155	75	80	3.20
10	60	875	0.40	66.52	1.00	499.61	400	315	50	154	75	79	3.20
11	63	930	0.40	67.88	1.00	501.33	400	305	52	145	75	80	3.20
11	66	840	0.38	63.98	1.00	503.22	400	300	52	145	75	80	3.30
12	69	860	0.38	64.47	1.00	505.01	400	295	55	138	75	80	3.30
12	72	860	0.38	64.47	1.00	507.02	400	290	54	135	75	80	3.30

Table IV.2 : Field Sampling Data for Preliminary Survey, Shell-Waterton Traverse #1, September 4, 1982

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)
									IMPINGERS		GAS METER		
							PROBE	OVEN	OUTLET	INLET	OUT	IN	
0	0	875	0.40	66.52	1.00	509.12	400	337	59	58	69	70	3.50
12	3	875	0.40	66.52	1.00	511.08	400	337	59	58	69	70	3.50
12	6	875	0.38	64.83	1.00	512.99	400	338	61	141	70	71	3.50
11	9	880	0.38	64.96	1.00	514.91	400	328	60	144	70	72	3.50
11	12	880	0.39	65.81	1.00	516.83	400	331	50	148	70	72	3.50
10	15	890	0.39	66.05	1.00	518.74	400	340	50	145	70	73	3.50
10	18	890	0.40	66.89	1.00	520.65	400	338	49	145	70	74	3.50
9	21	890	0.40	66.[illegible]	1.00	522.54	400	332	49	142	70	74	3.50
9	24	885	0.40	66.77	1.00	524.42	400	338	50	149	71	75	3.50
8	27	885	0.40	66.77	1.00	526.35	400	340	50	149	71	75	3.50
8	30	880	0.41	67.47	1.00	528.26	400	341	50	149	73	76	3.50
7	33	880	0.41	67.47	1.00	530.16	400	340	50	153	72	75	3.50
7	36	880	0.41	67.47	1.00	532.06	400	340	51	155	73	75	3.50
6	39	880	0.40	66.64	1.00	533.97	400	339	51	157	72	76	3.50
6	42	880	0.40	66.64	1.00	535.87	400	335	51	160	71	75	3.50
5	45	880	0.39	65.81	1.00	537.77	400	340	51	160	71	75	3.50
5	48	875	0.38	64.83	1.00	539.67	400	335	51	164	71	77	3.50
4	51	880	0.38	64.96	1.00	541.58	400	330	52	160	71	75	3.50
4	54	875	0.34	61.33	1.00	543.48	400	330	52	161	71	75	3.50
3	57	880	0.35	62.34	1.00	545.39	400	331	52	161	72	77	3.50
3	60	875	0.27	54.65	1.00	547.30	400	332	53	162	72	76	3.50
2	63	870	0.27	54.55	1.00	549.21	400	335	52	164	71	76	3.50
2	66	865	0.14	39.21	1.00	551.12	400	331	52	162	71	75	3.50
1	69	865	0.14	39.21	1.00	553.04	400	331	52	161	72	77	3.50
1	72	865	0.14	39.21	1.00	554.96	400	331	53	160	72	77	3.50

Table IV.3 : Field Sampling Data for Preliminary Survey, Shell-Waterton Traverse #2. September 4, 1982

Sample Analyses Test No Prelim Date September 4, /82 Waterton

Sample From	P&N 6M HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
	Micrograms						
Volume (ml)	440	610	320	-	$E_R = 1.6 \times 10^4$ kg/d (total)		
Total Particulate (mg)	26	3900	-	11	$E_R = 1.5 \times 10^2$ kg/d (front end)		
Cu Copper	$\boxed{15}$	12	$\boxed{11}$	10	$\boxed{48}$	$\boxed{0.63}$	$\boxed{8.3}$
Cr Chromium	31	24	$\boxed{30}$	20	$\boxed{110}$	$\boxed{1.4}$	$\boxed{19}$
Fe Iron	$\boxed{480}$	$\boxed{37}$	$\boxed{54}$	$\boxed{20}$	$\boxed{600}$	$\boxed{7.8}$	$\boxed{100}$
Mn Manganese	$\boxed{22}$	6.1	6.4	5.0	$\boxed{40}$	$\boxed{0.52}$	$\boxed{6.8}$
Sn Tin	$\boxed{260}$	120	96	100	$\boxed{580}$	$\boxed{7.6}$	$\boxed{100}$
Zn Zinc	$\boxed{75}$	$\boxed{49}$	$\boxed{16}$	$\boxed{24}$	$\boxed{160}$	$\boxed{2.1}$	$\boxed{28}$

All values except those in ☐ are below the limit of detection

Table IV.4 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell-Waterton Plant:
Preliminary Survey Glass Li

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: WATERTON

COMPANY: SHELL

2) TEST NO: 1 DATE: September 5, 1982

3) PRODUCTION: 2.61×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)

STATIC PRESSURE: -2.7 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 15 1/8 (feet)

5) PITOT TUBE COEFFICIENT: 0.896

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.25 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 10.37 , O_2 10.13 , CO 0.0

SO_2 0.04 , N_2 78.53 , Ar 0.93

7) NO. OF READINGS: 48

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 12

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 170.6 (grams)

WATER CAUGHT BY DRYING AGENTS: -7.0 (grams)

MOISTURE CONTENT, B_{wo}: 0.104

9) MOLECULAR WEIGHT OF GAS:

30.19 DRY BASIS (lb_m/lb mole)

28.92 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 87.20 (acf)

11) AVERAGE STACK VELOCITY: 61.14 (ft/s); AVG. TEMP: 875 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 659000 (acfm)

TABLE IV.5 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	895	0.20	47.10	0.22	582.75	398	230	66	64	62	61	0.50	0.00
1	4	895	0.20	47.10	0.22	583.95	398	230	66	64	62	61	0.50	90.86
1	8	865	0.20	46.57	0.22	585.22	400	309	59	117	62	62	0.50	95.20
2	12	870	0.26	53.20	0.29	586.64	399	331	58	137	63	64	0.50	93.44
2	16	875	0.26	53.30	0.29	588.23	395	348	57	148	67	65	0.50	103.80
3	20	875	0.35	61.84	0.39	590.03	395	340	56	149	67	68	1.00	101.75
3	24	875	0.35	61.84	0.39	591.75	393	335	54	144	68	69	1.00	96.31
4	28	870	0.39	65.16	0.43	593.67	388	328	53	141	68	69	1.50	102.13
4	32	875	0.39	65.20	0.43	595.66	384	336	55	149	68	70	1.50	105.09
5	36	875	0.39	65.28	0.43	597.46	393	343	55	152	69	70	1.50	96.10
5	40	875	0.39	65.28	0.43	599.42	393	348	56	153	71	72	1.50	103.59
6	44	878	0.41	67.01	0.46	601.29	396	352	56	159	71	73	1.50	96.63
6	48	880	0.41	67.06	0.46	603.37	398	355	56	158	73	74	1.50	107.42
7	52	885	0.42	68.00	0.47	605.23	400	358	58	163	72	74	1.50	94.89
7	56	885	0.42	68.00	0.47	607.24	403	361	58	162	72	75	1.50	102.46
8	60	885	0.42	68.00	0.47	609.21	407	348	58	160	72	75	1.50	100.76
8	64	880	0.42	67.87	0.47	611.22	408	345	58	152	73	76	1.50	102.40
9	68	877	0.40	66.16	0.45	613.29	410	338	59	160	73	76	1.50	107.58
9	72	875	0.40	66.11	0.45	615.29	411	338	59	159	75	77	1.50	103.84
10	76	879	0.38	64.53	0.43	617.07	415	336	59	149	75	78	1.50	94.80
10	80	878	0.38	64.51	0.43	618.84	418	335	60	148	76	78	1.00	94.16
11	84	870	0.39	65.16	0.44	620.60	449	334	61	142	78	79	1.00	91.71
11	88	877	0.40	66.16	0.45	622.59	423	333	61	142	77	79	1.50	102.79
12	92	885	0.38	64.68	0.43	624.31	429	331	61	134	79	79	1.50	91.36
12	96	885	0.38	64.68	0.43	626.25	436	329	61	130	78	79	1.50	102.98

Table IV.6 : Field Sampling Data for Test #1, Shell-Waterton, Traverse #1. September 5, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	850	0.08	29.29	0.09	626.25	390	304	78	74	70	69	0.25	0.00
1	4	850	0.08	29.29	0.09	627.07	390	304	78	74	70	69	0.25	95.62
1	8	845	0.08	29.23	0.09	627.99	396	332	73	114	72	71	0.25	106.89
2	12	837	0.26	52.54	0.30	629.57	394	351	69	129	72	71	0.75	100.74
2	16	865	0.26	53.10	0.30	631.16	393	352	64	142	73	72	0.75	102.31
3	20	865	0.32	58.91	0.36	633.60	393	370	64	153	74	73	1.00	107.16
3	24	861	0.32	58.82	0.36	634.77	393	359	63	159	75	75	1.00	102.16
4	28	865	0.38	64.20	0.43	636.81	395	351	62	163	76	75	1.50	108.42
4	32	875	0.38	64.44	0.43	638.53	395	341	62	162	77	77	1.50	91.05
5	36	880	0.37	63.70	0.42	640.21	395	350	65	165	77	80	1.50	90.57
5	40	875	0.38	64.44	0.43	642.17	395	340	62	170	77	80	1.50	103.57
6	44	880	0.37	63.70	0.42	644.16	395	340	65	167	80	81	1.50	106.94
6	48	880	0.38	64.56	0.43	646.23	395	340	65	167	80	81	1.50	109.41
7	52	880	0.39	65.40	0.44	648.03	400	345	65	165	80	82	1.50	93.83
7	56	870	0.38	64.32	0.44	649.90	405	345	65	170	81	83	1.50	98.26
8	60	865	0.40	65.86	0.46	651.96	405	345	65	155	80	85	1.50	105.05
8	64	865	0.40	65.86	0.46	654.04	405	345	65	165	80	87	1.50	105.95
9	68	880	0.41	67.06	0.47	655.81	405	345	65	160	80	82	1.80	90.28
9	72	885	0.42	68.00	0.48	657.96	410	340	65	155	80	82	1.80	108.09
10	76	890	0.42	68.12	0.48	659.86	415	345	65	160	60	82	2.00	96.00
10	80	890	0.42	68.12	0.48	661.91	415	345	65	152	60	82	2.00	103.12
11	84	890	0.41	67.31	0.46	663.76	415	345	65	152	80	82	2.00	94.70
11	88	885	0.40	66.36	0.45	665.70	420	345	65	150	79	81	1.90	100.10
12	92	885	0.41	67.18	0.46	667.82	425	345	62	140	78	80	1.90	108.32
12	96	480	0.41	67.06	0.46	669.95	420	345	62	140	78	80	1.90	108.92

Table IV.7 : Field Sampling Data for Test #1, Shell-Waterton, Traverse #2, September 5, 1982

Sample Analyses Test No 1 Date September 5,/82 Waterton

Sample From	P&N 0.1M HNO_3	IMP. 1,2,3,	Micrograms IMP. 4,5	Filter	P&N H_2O	Total Elemental Weight µg	Elemental Concentration µg/scf	Elemental Emission Rate g/hr
Volume (ml)	80	780	250	-	420	E_R = 1.7 x 10^3 kg/d (total)		
Total Particulate (mg)	84	134	-	7.6	84	E_R = 9.8 x 10^2 kg/d (front end)		
Al Aluminum	$\boxed{640}$	160	100	100	130	$\boxed{1100}$	$\boxed{20}$	$\boxed{260}$
Cu Copper	$\boxed{110}$	16	$\boxed{20}$	$\boxed{70}$	$\boxed{230}$	$\boxed{440}$	$\boxed{7.9}$	$\boxed{100}$
Cr Chromium	$\boxed{96}$	23	$\boxed{30}$	20	$\boxed{2100}$	$\boxed{2300}$	$\boxed{40}$	$\boxed{530}$
Fe Iron	$\boxed{750}$	$\boxed{480}$	$\boxed{50}$	$\boxed{20}$	$\boxed{12000}$	$\boxed{13000}$	$\boxed{230}$	$\boxed{3000}$
Li Lithium	$\boxed{140}$	3.9	2.5	4.0	4.2	$\boxed{160}$	$\boxed{2.8}$	$\boxed{37}$
Mn Manganese	$\boxed{130}$	$\boxed{7.8}$	5.0	5.0	$\boxed{460}$	$\boxed{510}$	$\boxed{11}$	$\boxed{140}$
Ni Nickel	$\boxed{160}$	23	20	20	$\boxed{1100}$	$\boxed{1300}$	$\boxed{23}$	$\boxed{310}$
Pb Lead	$\boxed{41}$	23	7.5	20	29	$\boxed{120}$	$\boxed{2.1}$	$\boxed{28}$
Sc Scandium	40	39	$\boxed{80}$	40	42	$\boxed{240}$	$\boxed{4.3}$	$\boxed{56}$
Sr Strontium	$\boxed{6}$	2.3	2.0	2.0	2.9	$\boxed{17}$	$\boxed{0.31}$	$\boxed{4.0}$
Zn Zinc	$\boxed{160}$	$\boxed{45}$	$\boxed{21}$	$\boxed{22}$	$\boxed{130}$	$\boxed{380}$	$\boxed{5.8}$	$\boxed{89}$

All values except those in ☐ are below the limit of detection

Table IV.8 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell-Waterton Plant:
Test #1 Stainless Steel Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: WATERTON

COMPANY: SHELL

2) TEST NO: 2 DATE: September 6, 1982

3) PRODUCTION: 2.61×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)

STATIC PRESSURE: -2.6 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 15 1/8 (feet)

5) PITOT TUBE COEFFICIENT: 0.895

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 11.8, O_2 8.88, CO 0.0

SO_2 0.04, N_2 78.35, Ar 0.93

7) NO. OF READINGS: 48

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 12

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 224.9 (grams)

WATER CAUGHT BY DRYING AGENTS: 11.4 (grams)

MOISTURE CONTENT, B_{wo}: 0.088

9) MOLECULAR WEIGHT OF GAS:

30.37 DRY BASIS (lb_m/lb mole)

29.28 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 139.21 (acf)

11) AVERAGE STACK VELOCITY: 61.39 (ft/s); AVG. TEMP: 870 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 662000 (acfm)

TABLE IV.9 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	865	0.20	46.23	0.54	682.49	360	200	68	69	62	62	1.00	0.00
1	4	860	0.20	46.14	0.54	684.41	380	200	57	85	62	62	1.00	91.07
1	8	860	0.20	46.14	0.54	686.46	382	218	53	103	64	65	1.00	96.47
2	12	860	0.24	50.55	0.65	688.76	384	256	52	125	65	68	1.50	99.13
2	16	860	0.24	50.55	0.65	691.25	384	283	51	137	65	69	1.50	106.54
3	20	865	0.32	58.48	0.86	694.13	385	319	51	139	68	71	2.00	107.03
3	24	870	0.32	58.59	0.86	696.92	387	339	52	161	69	72	2.00	103.34
4	28	870	0.36	62.14	0.97	699.70	388	358	52	174	71	75	3.00	96.69
4	32	870	0.36	62.14	0.97	702.29	388	359	53	178	71	76	3.00	90.07
5	36	865	0.38	63.72	1.04	704.96	389	338	52	174	72	76	3.25	90.19
5	40	865	0.38	63.72	1.04	707.64	391	332	52	170	73	77	3.25	90.53
6	44	850	0.40	65.01	1.10	710.44	391	335	54	170	72	78	4.00	91.46
6	48	845	0.40	64.88	1.10	713.34	395	332	54	168	75	79	4.00	94.00
7	52	870	0.41	66.31	1.14	716.45	397	331	53	170	75	79	4.00	100.82
7	56	880	0.41	66.56	1.14	719.49	399	331	54	170	74	79	4.00	98.92
8	60	880	0.40	65.75	1.10	722.72	401	333	55	171	76	80	3.50	106.08
8	64	880	0.40	65.75	1.10	725.94	404	333	55	170	74	79	3.50	106.22
9	68	875	0.40	65.62	1.10	729.07	408	338	58	172	77	80	3.50	102.54
9	72	870	0.40	65.50	1.10	732.11	408	336	58	169	77	80	3.50	99.33
10	76	875	0.39	64.80	1.08	734.92	409	336	59	164	78	80	3.50	93.00
10	80	875	0.39	64.80	1.08	738.06	411	338	59	159	79	81	3.50	104.10
11	84	870	0.38	63.84	1.05	741.27	413	338	60	158	77	81	3.00	107.52
11	88	870	0.38	63.84	1.05	744.50	416	338	61	156	78	81	3.00	108.22
12	92	875	0.40	65.62	1.10	747.61	421	342	60	159	77	81	3.50	101.64
12	96	875	0.40	65.62	1.10	750.54	426	342	58	150	78	81	3.50	95.87

Table IV.10: Field Sampling Data for Test #2, Shell-Waterton, Traverse #1, September 6, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	865	0.21	47.37	0.58	750.54	392	200	70	72	76	76	2.00	0.00
1	4	865	0.21	47.37	0.58	752.76	392	200	70	72	76	76	2.00	100.42
1	8	850	0.21	47.10	0.58	754.99	394	252	55	121	78	79	2.00	99.67
2	12	860	0.24	50.55	0.67	757.24	394	300	54	135	79	80	2.00	94.22
2	16	865	0.30	56.62	0.83	760.12	392	324	54	151	79	80	2.50	108.20
3	20	865	0.33	59.38	0.92	762.95	391	343	54	163	79	81	2.50	101.22
3	24	865	0.33	59.38	0.92	765.56	395	343	56	170	79	81	2.50	93.57
4	28	865	0.38	63.72	1.06	768.27	394	340	54	170	80	82	3.50	90.35
4	32	865	0.38	63.72	1.06	771.27	397	340	55	174	80	83	3.50	99.98
5	36	870	0.39	64.68	1.08	774.51	399	342	55	172	80	84	4.00	106.64
5	40	865	0.39	64.55	1.08	777.56	395	345	55	175	80	85	4.00	100.04
6	44	870	0.40	65.50	1.11	780.66	399	348	53	178	81	84	4.00	100.47
6	48	870	0.40	65.50	1.11	783.82	401	349	54	177	81	85	4.00	102.44
7	52	870	0.40	65.50	1.11	786.60	402	349	55	178	80	84	4.00	90.36
7	56	865	0.40	65.38	1.11	789.70	408	349	58	178	81	86	4.00	100.19
8	60	870	0.40	65.50	1.11	793.03	408	351	58	175	81	87	3.75	107.87
8	64	870	0.40	65.50	1.11	796.29	409	354	59	174	81	87	3.75	105.48
9	68	875	0.41	66.44	1.14	799.48	412	357	59	169	82	88	4.00	102.06
9	72	875	0.41	66.44	1.14	802.70	412	358	59	172	82	88	4.00	103.02
10	76	875	0.42	67.24	1.17	805.85	416	359	58	163	82	88	4.00	99.58
10	80	870	0.41	66.31	1.17	808.68	419	358	58	168	82	88	4.00	90.22
11	84	870	0.41	66.31	1.17	811.97	419	359	59	162	82	88	4.00	105.12
11	88	870	0.41	66.31	1.17	815.07	424	359	60	165	82	89	4.00	98.68
12	92	865	0.40	65.38	1.11	818.36	429	361	60	159	83	89	4.00	106.00
12	96	870	0.40	65.50	1.11	821.71	429	365	61	155	83	89	4.00	107.86

Table IV.11: Field Sampling Data for Test #2, Shell-Waterton, Traverse #2, September 6, 1982

Sample Analyses Test No 2 Date September 6/82 Waterton

Sample From	P&N H_2O	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
	Micrograms						
Volume (ml)	400	845	275	-	$E_R = 2.0 \times 10^4$ kg/d (total)		
Total Particulate (mg)	37	5900	-	8	$E_R = 1.5 \times 10^2$ kg/d (front end)		
Cd Cadminium	$\boxed{32}$	2.5	2.2	2.0	$\boxed{39}$	$\boxed{0.41}$	$\boxed{5.4}$
Cu Copper	$\boxed{160}$	8.5	$\boxed{22}$	$\boxed{10}$	$\boxed{200}$	$\boxed{2.1}$	$\boxed{28}$
Cr Chromium	$\boxed{960}$	$\boxed{36}$	$\boxed{55}$	20	$\boxed{1100}$	$\boxed{11}$	$\boxed{150}$
Fe Iron	$\boxed{5200}$	$\boxed{160}$	$\boxed{200}$	$\boxed{20}$	$\boxed{5600}$	$\boxed{58}$	$\boxed{770}$
Pb Lead	28	25	$\boxed{14}$	20	$\boxed{88}$	$\boxed{0.9}$	$\boxed{12}$
Mn Manganese	$\boxed{170}$	85	5.5	5.0	$\boxed{190}$	$\boxed{2.0}$	$\boxed{26}$
Ni Nickel	$\boxed{720}$	25	$\boxed{44}$	20	$\boxed{810}$	$\boxed{8.5}$	$\boxed{110}$
Sc Scandium	$\boxed{52}$	$\boxed{34}$	$\boxed{28}$	40	$\boxed{150}$	$\boxed{1.6}$	$\boxed{21}$
Sn Tin	120	$\boxed{140}$	110	100	$\boxed{470}$	$\boxed{5.0}$	$\boxed{66}$
Zn Zinc	$\boxed{120}$	$\boxed{79}$	$\boxed{25}$	$\boxed{14}$	$\boxed{240}$	$\boxed{2.5}$	$\boxed{33}$

All values except those in boxes ☐ are below the limit of detection

Table IV.12 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell-Waterton Plant:
Test #2 Stainless Steel Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD
LOCATION: WATERTON
COMPANY: SHELL

2) TEST NO: 3 DATE: September 7, 1982

3) PRODUCTION: 2.53×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)
STATIC PRESSURE: -2.8 (inches H_2O)
STACK DIMENSIONS: DIAMETER (D) 15 1/8 (feet)

5) PITOT TUBE COEFFICIENT: 0.895
METER CORRECTION FACTOR: 1.0
NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)
CO_2 9.06, O_2 9.74, CO 0.0
SO_2 0.04, N_2 80.21, Ar 0.95

7) NO. OF READINGS: 48
TIME BETWEEN READINGS: 4 min.
TEST POINTS/TRAVERSE: 12
NO. OF TRAVERSES: 2

8) CONDENSED WATER: 222.4 (grams)
WATER CAUGHT BY DRYING AGENTS: 12.2 (grams)
MOISTURE CONTENT, B_{wo}: 0.088

9) MOLECULAR WEIGHT OF GAS:
29.97 DRY BASIS (lb_m/lb mole)
28.91 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 137.49 (acf)

11) AVERAGE STACK VELOCITY: 61.40 (ft/s); AVG.TEMP: 870 (°F)
AVERAGE VOLUMETRIC FLOW RATE: 662000 (acfm)

TABLE IV.13 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	865	0.21	47.69	0.57	852.14	399	272	68	67	62	61	2.50	0.00
1	4	865	0.21	47.69	0.57	854.16	399	272	68	67	62	61	2.50	93.24
1	8	865	0.21	47.69	0.57	856.14	394	308	54	129	62	62	2.00	91.45
2	12	870	0.26	53.16	0.70	858.35	394	329	54	139	63	65	2.25	91.36
2	16	865	0.26	53.06	0.70	860.74	392	341	54	148	65	68	2.25	98.17
3	20	870	0.31	58.05	0.86	863.57	391	354	55	160	67	68	3.00	106.81
3	24	870	0.31	58.05	0.86	866.16	392	366	56	169	68	70	3.00	97.26
4	28	870	0.32	58.98	0.88	868.93	392	351	58	166	69	71	3.00	102.22
4	32	870	0.33	59.89	0.91	871.63	393	338	56	161	69	72	3.00	98.03
5	36	875	0.36	62.67	0.99	874.74	396	334	57	159	72	73	3.00	108.11
5	40	870	0.36	62.55	0.99	877.81	396	338	58	160	71	74	3.00	106.37
6	44	875	0.38	64.39	1.05	880.93	399	339	57	160	72	76	3.50	105.21
6	48	875	0.38	64.39	1.05	883.74	400	339	58	161	77	78	3.50	93.93
7	52	870	0.38	64.27	1.05	886.62	401	339	58	159	73	77	3.50	96.60
7	56	875	0.40	66.06	1.10	889.49	403	339	58	159	72	78	3.50	94.24
8	60	870	0.40	65.94	1.10	892.43	407	341	58	162	75	79	3.50	96.03
8	64	865	0.40	65.81	1.10	895.75	409	341	58	156	74	79	3.50	107.99
9	68	870	0.40	65.94	1.10	898.93	412	342	59	153	77	79	3.50	103.65
9	72	875	0.40	66.06	1.10	902.30	415	342	59	153	76	79	3.50	109.97
10	76	875	0.40	66.06	1.10	905.60	419	343	61	149	61	80	3.50	106.99
10	80	870	0.40	65.94	1.10	908.43	420	342	61	152	76	79	3.50	92.17
11	84	870	0.38	64.27	1.05	911.12	422	349	62	156	75	79	3.75	90.11
11	88	870	0.38	64.27	1.05	913.85	427	350	62	157	75	79	3.50	91.14
12	92	865	0.34	60.68	0.94	916.56	429	355	64	149	75	79	3.50	95.83
12	96	870	0.36	62.55	0.99	919.33	438	362	64	141	78	80	3.00	94.67

Table IV.14: Field Sampling Data for Test #3, Shell-Waterton, Traverse #1, September 7, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	865	0.10	32.91	0.28	919.33	391	230	73	69	68	67	1.00	0.00
1	4	865	0.10	32.91	0.28	920.93	391	230	73	69	68	67	1.00	105.61
1	8	865	0.10	32.91	0.28	922.47	389	272	63	120	69	69	1.00	101.63
2	12	870	0.32	58.98	0.88	925.16	390	309	62	132	72	69	3.00	99.19
2	16	865	0.34	60.68	0.94	927.97	390	328	62	141	69	70	3.00	100.46
3	20	875	0.36	62.67	0.99	930.56	390	351	64	159	71	73	3.25	90.03
3	24	870	0.36	62.55	0.99	933.32	391	360	66	165	71	72	3.25	96.03
4	28	870	0.38	64.27	1.05	936.47	394	377	68	171	73	75	3.50	105.8[illegible]
4	32	865	0.38	64.15	1.05	939.17	396	362	66	170	73	75	3.50	90.78
5	36	865	0.39	64.99	1.08	941.96	396	344	66	161	74	77	3.50	92.10
5	40	870	0.41	66.76	1.13	944.92	398	331	66	159	75	78	3.75	95.57
6	44	870	0.42	67.57	1.16	948.22	401	331	66	165	77	80	4.00	104.49
6	48	870	0.42	67.57	1.16	951.58	400	337	66	156	78	80	4.00	106.78
7	52	875	0.42	67.69	1.16	954.74	401	338	66	161	78	81	4.00	100.29
7	56	875	0.42	67.69	1.16	957.92	401	336	63	156	79	81	4.00	100.68
8	60	870	0.44	69.16	1.21	961.20	408	338	61	156	79	81	4.00	101.39
8	64	870	0.44	69.16	1.21	964.50	407	338	61	159	78	80	4.00	102.22
9	68	870	0.44	69.16	1.21	967.75	409	341	64	152	77	81	4.00	100.83
9	72	870	0.44	69.16	1.21	971.14	410	344	66	156	78	81	4.00	105.02
10	76	875	0.42	67.69	1.16	974.38	411	347	67	151	79	81	4.00	102.55
10	80	875	0.42	67.69	1.16	977.21	411	351	62	158	77	80	3.75	90.15
11	84	875	0.40	66.06	1.10	980.22	417	352	62	149	77	80	4.00	97.92
11	88	870	0.40	65.94	1.10	983.18	418	355	66	157	78	81	3.50	96.16
12	92	875	0.42	67.69	1.16	986.20	425	364	67	158	79	81	4.00	95.71
12	96	875	0.42	67.69	1.16	989.63	431	359	68	152	79	81	4.00	108.75

Table IV.15: Field Sampling Data for Test #3, Shell-Waterton, Traverse #2, September 7, 1982.

Sample Analyses Test No 3 Date September 7/82 Waterton

Sample From	P&N 0.1M HNO_3	Micrograms IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concen-tration µg/rcf	Elemental Emission Rate g/hr
Volume (ml)	*	845	270	-	$E_R = 2.3 \times 10^4$ kg/d (total)		
Total Particulate (mg)	27	7200	-	7	$E_R = 1.5 \times 10^2$ kg/d (front end)		
Al Aluminum	*	85	110	$\boxed{50}$	$\boxed{190}$	$\boxed{1.9}$	$\boxed{25}$
Cu Copper	*	$\boxed{11}$	$\boxed{11}$	$\boxed{10}$	$\boxed{32}$	$\boxed{0.31}$	$\boxed{4.1}$
Fe Iron	*	$\boxed{85}$	$\boxed{190}$	$\boxed{20}$	$\boxed{290}$	$\boxed{2.8}$	$\boxed{38}$
Mn Manganese	*	5.9	$\boxed{5.4}$	5.0	$\boxed{16}$	$\boxed{0.16}$	$\boxed{2.1}$
Zn Zinc	*	$\boxed{59}$	$\boxed{27}$	$\boxed{15}$	$\boxed{100}$	$\boxed{1.0}$	$\boxed{13}$

All values except those in boxes ☐ are below the limit of detection

*Sample Destroyed

Table IV.16 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell-Wateron Plant:
Test #3 Stainless Steel Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD
LOCATION: WATERTON
COMPANY: SHELL

2) TEST NO: 4 DATE: September 8, 1982

3) PRODUCTION: 2.73×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)
STATIC PRESSURE: -2.7 (inches H_2O)
STACK DIMENSIONS: DIAMETER (D)15 1/8 (feet)

5) PITOT TUBE COEFFICIENT: 0.895
METER CORRECTION FACTOR: 1.0
NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)
CO_2 5.88 , O_2 10.82 , CO 0.0
SO_2 0.04 , N_2 82.28 , Ar 0.98

7) NO. OF READINGS: 56
TIME BETWEEN READINGS: 4 min.
TEST POINTS/TRAVERSE: 14
NO. OF TRAVERSES: 2

8) CONDENSED WATER: 282.4 (grams)
WATER CAUGHT BY DRYING AGENTS: 15.2 (grams)
MOISTURE CONTENT, B_{wo}: 0.106

9) MOLECULAR WEIGHT OF GAS:
29.51 DRY BASIS (lb_m/lb mole)
28.28 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 142.17 (acf)

11) AVERAGE STACK VELOCITY:64.73(ft/s); AVG.TEMP: 871 (°F)
AVERAGE VOLUMETRIC FLOW RATE:698000 (acfm)

TABLE IV.17 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	865	0.21	48.20	0.58	18.90	395	205	75	75	65	62	2.00	0.00
1	4	865	0.21	48.20	0.58	20.88	395	205	75	75	65	62	2.00	91.70
1	8	865	0.21	48.20	0.58	22.85	388	313	71	137	63	64	2.00	91.62
2	12	870	0.32	59.62	0.88	25.51	380	339	71	150	65	68	2.50	99.70
2	16	870	0.32	59.62	0.88	28.01	388	349	62	156	66	68	2.50	93.65
3	20	870	0.41	67.48	1.12	31.18	390	342	62	161	67	69	3.25	104.62
3	24	865	0.41	67.35	1.12	34.37	391	339	62	160	68	71	3.25	104.82
4	28	870	0.41	67.48	1.12	37.63	392	338	62	159	69	72	3.25	107.34
4	32	870	0.41	67.40	1.12	40.70	396	331	62	158	71	74	3.25	100.69
5	36	870	0.41	67.48	1.12	43.70	399	322	63	149	71	74	3.25	98.07
5	40	875	0.41	67.61	1.12	46.81	398	338	65	159	71	75	3.25	102.17
6	44	870	0.40	66.65	1.10	49.54	399	342	65	162	71	76	3.25	90.39
6	48	870	0.41	67.48	1.12	52.69	401	351	64	159	71	77	3.25	102.85
7	52	870	0.44	69.91	1.21	55.97	401	360	64	169	71	77	3.50	103.60
7	56	875	0.44	70.04	1.21	59.01	404	339	66	171	72	78	3.50	95.93
8	60	875	0.43	69.24	1.18	62.25	406	342	68	162	72	79	3.50	103.15
8	64	875	0.43	69.24	1.18	65.25	409	342	68	161	73	79	3.50	95.56
9	68	875	0.44	70.04	1.21	68.59	411	335	69	152	74	81	3.50	104.99
9	72	875	0.45	70.83	1.23	72.14	416	332	68	149	75	81	3.50	109.91
10	76	870	0.42	68.30	1.15	75.09	418	332	66	150	76	81	3.50	91.55
10	80	875	0.42	68.43	1.15	78.15	419	328	68	144	77	81	3.50	98.09
11	84	875	0.41	67.61	1.12	81.16	421	331	68	117	78	81	3.50	97.59
11	88	875	0.41	67.61	1.12	84.33	424	331	68	118	78	81	3.50	102.67
12	92	875	0.41	67.61	1.12	87.35	428	319	64	142	78	81	3.25	97.72
12	96	875	0.43	69.24	1.18	90.58	429	332	62	139	77	81	3.25	102.34

Table IV.18 : Field Sampling Data for Test #4, Shell-Waterton, Traverse #1, September 8, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	865	0.26	53.64	0.71	90.58	400	205	78	78	72	71	2.50	0.00
1	4	865	0.26	53.64	0.71	92.88	400	205	78	78	72	71	2.50	94.53
1	8	870	0.26	53.74	0.71	95.47	401	271	61	124	73	75	2.50	106.12
2	12	865	0.38	64.84	1.04	98.61	399	310	59	134	76	78	3.00	105.97
2	16	865	0.36	63.11	0.99	101.53	399	330	59	142	77	79	3.00	100.73
3	20	865	0.36	63.11	0.99	104.16	398	348	59	151	79	80	3.25	90.64
3	24	870	0.36	63.23	0.99	106.98	398	363	61	160	79	80	3.00	97.25
4	28	870	0.38	64.96	1.04	110.19	400	352	61	170	80	81	3.25	107.70
4	32	870	0.38	64.96	1.04	112.91	401	340	61	160	80	82	3.25	90.96
5	36	865	0.40	66.53	1.10	115.88	399	331	60	157	81	83	3.25	96.46
5	40	870	0.40	66.65	1.10	118.95	402	326	60	158	81	83	3.25	100.13
6	44	870	0.42	68.30	1.15	121.86	405	322	61	153	81	83	3.50	92.67
6	48	875	0.42	68.43	1.15	124.85	406	322	60	152	82	85	3.50	91.82
7	52	870	0.42	68.30	1.15	127.84	409	319	60	149	82	86	3.50	94.90
7	56	875	0.42	68.43	1.15	130.87	408	320	61	148	83	88	3.50	96.06
8	60	875	0.40	66.78	1.10	134.02	409	321	61	144	83	88	3.50	102.23
8	64	870	0.40	66.65	1.10	137.39	411	321	61	143	83	88	3.50	108.87
9	68	875	0.40	66.78	1.10	140.26	416	315	62	149	83	88	3.50	93.14
9	72	870	0.40	66.65	1.10	143.31	418	319	62	145	83	87	3.50	99.04
10	76	875	0.38	65.09	1.05	146.20	421	319	62	147	83	88	3.25	95.94
10	80	875	0.37	64.22	1.01	149.29	422	319	61	144	84	88	3.00	104.26
11	84	875	0.38	65.09	1.05	152.35	426	319	61	141	82	87	3.00	102.11
11	88	875	0.38	65.09	1.05	155.19	429	318	62	143	83	87	3.00	94.33
12	92	875	0.36	63.35	0.99	158.31	432	314	63	139	82	86	3.00	107.04
12	96	875	0.37	64.22	1.01	161.07	433	321	64	134	83	87	3.00	93.25

Table IV.19 : Field Sampling Data for Test #4, Shell-Waterton, Traverse #2, September 8, 1982

Sample Analyses	Test No 4		Date	September 8/82		Waterton	
	Micrograms				Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
Sample From	P&N 6M HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter			
Volume (ml)	470	840	250	-	$E_R = 3.6 \times 10^4$ kg/d (total)		
Total Particulate (mg)	55	11000	-	-	$E_R = 2.5 \times 10^2$ kg/d (front end)		
Cu Copper	$\boxed{40}$	8.4	$\boxed{10}$	$\boxed{70}$	$\boxed{130}$	$\boxed{1.2}$	$\boxed{17}$
Cr Chromium	$\boxed{40}$	$\boxed{25}$	$\boxed{30}$	20	$\boxed{120}$	$\boxed{1.1}$	$\boxed{15}$
Fe Iron	$\boxed{460}$	$\boxed{72}$	$\boxed{50}$	$\boxed{20}$	$\boxed{600}$	$\boxed{5.7}$	$\boxed{78}$
Sc Scandium	19	84	$\boxed{75}$	40	$\boxed{220}$	$\boxed{2.1}$	$\boxed{29}$
Se Selenium	1.4	$\boxed{2.2}$	1.0	1.0	$\boxed{5.6}$	$\boxed{0.05}$	$\boxed{0.70}$
Zn Zinc	$\boxed{44}$	$\boxed{54}$	$\boxed{30}$	$\boxed{24}$	$\boxed{150}$	$\boxed{1.5}$	$\boxed{20}$

All values except those in boxes $\boxed{}$ are below the limit of detection

Table IV.20 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell-Waterton Plant:
Test #4 Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: WATERTON

COMPANY: SHELL

2) TEST NO: 5 DATE: October 6, 1982

3) PRODUCTION: 2.32×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.80 (inches Hg)

STATIC PRESSURE: -2.8 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 15 1/8 (feet)

5) PITOT TUBE COEFFICIENT: .895

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 6.46 , O_2 8.92 , CO 0.0

SO_2 0.04 , N_2 83.59 , Ar 0.99

7) NO. OF READINGS: 56

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 14

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 254.3 (grams)

WATER CAUGHT BY DRYING AGENTS: 10.6 (grams)

MOISTURE CONTENT, B_{wo}: 0.095

9) MOLECULAR WEIGHT OF GAS:

30.73 DRY BASIS (lb_m/lb mole)

29.52 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 143.82 (acf)

11) AVERAGE STACK VELOCITY: 54.67 (ft/s); AVG. TEMP: 835 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 589000 (acfm)

TABLE IV. 21 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	850	0.08	29.01	0.21	187.26	380	60	45	45	45	45	0.50	0.00
1	4	850	0.08	29.01	0.21	188.44	380	210	45	65	45	45	0.50	92.18
1	8	850	0.08	29.01	0.21	189.78	380	240	50	75	50	50	0.50	103.07
2	12	850	0.08	29.01	0.21	191.18	380	270	50	100	50	50	0.50	108.80
2	16	850	0.08	29.01	0.21	192.55	380	290	50	100	50	50	0.50	105.20
3	20	800	0.22	47.19	0.59	194.56	370	250	50	100	50	50	1.00	91.99
3	24	830	0.32	57.58	0.87	197.30	370	250	50	100	50	50	1.00	105.16
4	28	830	0.32	57.58	0.87	199.98	370	250	50	100	50	50	1.00	103.05
4	32	830	0.32	57.58	0.87	202.38	370	220	50	100	50	50	2.00	91.86
5	36	830	0.32	57.58	0.87	205.08	370	220	50	100	50	50	2.00	103.69
5	40	830	0.38	62.75	1.05	207.81	375	250	50	100	60	50	3.50	95.42
6	44	830	0.38	62.75	1.05	210.65	380	280	50	100	60	50	3.50	99.29
6	48	830	0.42	65.97	1.17	213.58	380	260	50	100	60	50	3.50	96.99
7	52	830	0.42	65.97	1.17	216.84	380	240	50	110	60	50	3.50	108.32
7	56	830	0.42	65.97	1.17	219.76	380	250	50	110	60	50	3.50	96.96
8	60	830	0.42	65.97	1.17	222.97	380	250	50	110	60	50	3.50	106.90
8	64	830	0.42	65.97	1.17	226.30	380	310	40	120	60	65	3.50	108.71
9	68	830	0.42	65.97	1.17	229.01	390	320	40	120	50	60	3.50	90.17
9	72	830	0.36	61.08	1.00	231.87	390	330	40	120	50	60	3.50	102.67
10	76	830	0.36	61.08	1.00	234.79	390	330	40	120	50	60	3.50	104.49
10	80	830	0.36	61.08	1.00	237.66	390	350	40	120	50	60	3.50	102.89
11	84	830	0.36	61.08	1.00	240.36	390	350	40	120	50	60	3.50	96.94
11	88	830	0.38	62.75	1.05	243.10	390	320	40	120	50	60	3.50	95.65
12	92	830	0.38	62.75	1.05	246.01	390	330	40	120	50	60	3.50	101.38
12	96	830	0.38	62.75	1.05	249.08	400	300	40	125	50	60	3.50	107.47
13	100	830	0.38	62.75	1.05	251.73	400	340	40	125	50	60	3.50	92.40
13	104	830	0.38	62.75	1.05	254.80	400	340	40	125	50	60	3.50	107.18
14	108	830	0.38	62.75	1.05	257.42	400	340	40	125	50	60	3.50	91.46
14	112	830	0.38	62.75	1.05	260.41	400	340	40	125	50	60	3.50	104.10

Table IV.22: Field Sampling Data for Test #5, Shell-Waterton, Traverse #1, October 6, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	830	0.02	14.40	0.05	260.41	370	180	50	50	50	50	0.50	0.00
1	4	830	0.02	14.40	0.05	261.07	370	280	50	90	50	60	0.50	101.51
1	8	830	0.02	14.40	0.05	261.68	370	300	50	95	50	60	0.50	92.22
2	12	830	0.02	14.40	0.05	262.34	370	320	50	95	50	60	0.50	99.59
2	16	830	0.02	14.40	0.05	263.05	370	320	50	95	50	60	0.50	107.40
3	20	830	0.14	38.09	0.39	264.95	370	350	50	130	60	60	1.50	108.20
3	24	830	0.26	51.90	0.72	267.40	370	320	50	140	60	60	2.50	102.40
4	28	830	0.26	51.90	0.72	269.91	370	330	50	150	60	60	2.50	100.56
4	32	830	0.30	55.75	0.83	272.43	370	350	50	150	60	60	3.00	101.71
5	36	840	0.30	55.97	0.83	275.13	370	350	50	150	60	60	3.00	105.31
5	40	840	0.36	61.31	0.98	277.83	370	340	50	150	60	60	3.00	96.36
6	44	840	0.36	61.31	0.98	280.36	370	340	50	150	60	60	3.00	90.40
6	48	840	0.38	62.99	1.03	283.11	370	330	50	150	60	60	3.50	95.18
7	52	840	0.38	62.99	1.03	285.92	370	320	50	140	60	60	3.50	97.43
7	56	840	0.38	62.99	1.07	289.05	370	320	50	140	60	70	3.50	107.87
8	60	840	0.38	62.99	1.07	291.68	370	340	50	140	60	70	3.50	90.42
8	64	840	0.38	62.99	1.07	294.35	370	350	50	140	60	70	3.50	91.63
9	68	840	0.38	62.99	1.07	297.14	370	350	50	140	60	70	3.50	95.99
9	72	840	0.42	66.23	1.18	299.96	370	350	50	140	70	70	3.50	91.24
10	76	840	0.42	66.23	1.18	303.15	370	350	50	140	70	70	3.50	103.48
10	80	840	0.42	66.23	1.18	306.23	400	370	50	160	70	70	3.50	99.71
11	84	840	0.42	66.23	1.18	309.55	400	350	50	150	75	70	3.50	106.94
11	88	840	0.40	64.63	1.13	312.72	400	340	60	150	75	75	3.50	104.25
12	92	840	0.40	64.63	1.13	315.85	400	340	60	150	75	75	4.00	102.98
12	96	840	0.40	64.63	1.13	318.88	400	340	60	150	75	75	4.00	99.61
13	100	840	0.40	64.63	1.13	321.64	400	340	60	150	75	75	4.00	90.87
13	104	840	0.40	64.63	1.13	324.95	400	330	60	150	75	75	4.00	108.68
14	108	840	0.40	64.63	1.13	327.81	400	330	60	150	75	75	4.00	94.24
14	112	840	0.40	64.63	1.13	331.07	400	330	60	150	75	75	4.00	107.31

Table IV.23 : Field Sampling Data for Test #5, Shell-Waterton, Traverse #2
October 6, 1982.

Sample Analyses   Test No 5   Date October 6/82   Waterton

Sample From	P&N 6M HNO_3	Micrograms IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
Volume (ml)	+200	780	290	-	E_R = 2.2 x 10^4 kg/d (total)		
Total Particulate (mg)	5	7700	-	32	E_R = 1.0 x 10^2 kg/d (front end)		
Al Aluminum	200	390	290	$\boxed{50}$	$\boxed{930}$	$\boxed{9.0}$	$\boxed{110}$
Cu Copper	$\boxed{20}$	39	29	10	$\boxed{98}$	$\boxed{1.1}$	$\boxed{1.2}$
Fe Iron	$\boxed{40}$	$\boxed{78}$	$\boxed{58}$	$\boxed{30}$	$\boxed{210}$	$\boxed{2.0}$	$\boxed{24}$
Sb Antimony	80	$\boxed{230}$	120	20	$\boxed{450}$	$\boxed{4.4}$	$\boxed{53}$
Zn Zinc	$\boxed{50}$	$\boxed{70}$	$\boxed{38}$	$\boxed{19}$	$\boxed{180}$	$\boxed{1.7}$	$\boxed{21}$

All values except those in boxes ☐ are below the limit of detection

+part of probe and nozzle wash lost during analysis

Table IV. 24 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell-Waterton Plant:
Test #5 Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: WATERTON

COMPANY: SHELL

2) TEST NO: 6 DATE: October 7,1982

3) PRODUCTION: 2.39×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.76 (inches Hg)

STATIC PRESSURE: -2.7 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 15 1/8 (feet)

5) PITOT TUBE COEFFICIENT: .895

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 6.1 , O_2 10.75 , CO 0.0

SO_2 0.04 , N_2 82.13 , Ar 0.98

7) NO. OF READINGS: 56

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 14

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 273.8 (grams)

WATER CAUGHT BY DRYING AGENTS: 6.3 (grams)

MOISTURE CONTENT, B_{wo}: 0.096

9) MOLECULAR WEIGHT OF GAS:

29.59 DRY BASIS (lb_m/lb mole)

28.48 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 151.01 (acf)

11) AVERAGE STACK VELOCITY: 57.46 (ft/s); AVG.TEMP: 839 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 619000 (acfm)

TABLE IV.25 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	820	0.02	14.61	0.05	334.33	370	220	50	75	50	50	0.50	0.00
1	4	820	0.02	14.61	0.05	334.96	370	230	50	75	50	50	0.50	94.10
1	8	820	0.02	14.61	0.05	335.59	370	260	50	90	50	50	0.50	94.72
2	12	820	0.02	14.61	0.05	336.27	370	280	50	90	50	50	0.50	101.27
2	16	820	0.18	43.83	0.49	338.17	370	320	50	120	50	50	1.00	95.21
3	20	820	0.16	41.32	0.43	340.05	370	330	50	130	50	50	1.00	99.55
3	24	830	0.26	52.88	0.72	342.47	370	340	50	140	60	50	2.00	100.37
4	28	830	0.26	52.88	0.72	345.04	370	340	50	150	60	50	2.00	106.31
4	32	830	0.32	58.66	0.89	347.57	370	330	50	150	60	50	2.80	94.42
5	36	830	0.32	58.66	0.89	350.51	370	330	50	150	60	50	2.80	109.78
5	40	830	0.36	62.22	1.00	353.63	370	340	50	150	60	60	3.10	108.87
6	44	830	0.36	62.22	1.00	356.65	370	340	50	150	60	60	3.10	105.15
6	48	840	0.38	64.17	1.05	359.32	380	360	50	160	60	60	3.50	91.09
7	52	840	0.38	64.17	1.05	362.26	380	350	50	170	60	60	3.50	100.18
7	56	840	0.40	65.84	1.10	365.31	380	350	50	170	60	60	3.80	101.29
8	60	840	0.40	65.84	1.10	368.50	380	350	50	170	60	60	3.80	106.13
8	64	840	0.40	65.84	1.10	371.67	380	350	50	170	60	60	3.80	105.11
9	68	840	0.40	65.84	1.10	374.54	370	350	50	170	60	60	3.80	95.45
9	72	850	0.42	67.73	1.15	377.82	370	360	45	150	60	60	4.00	106.78
10	76	850	0.42	67.73	1.15	380.94	370	360	45	150	60	60	4.00	101.61
10	80	850	0.42	67.73	1.15	384.28	370	360	45	150	60	60	4.00	108.55
11	84	850	0.42	67.73	1.15	387.25	370	350	40	150	60	60	4.00	96.81
11	88	850	0.40	66.09	1.09	390.37	370	350	40	150	60	60	4.00	103.98
12	92	850	0.40	66.09	1.09	393.14	370	360	45	150	60	60	4.00	92.50
12	96	850	0.40	66.09	1.09	396.11	370	360	45	150	60	60	4.00	99.19
13	100	850	0.40	66.09	1.09	399.19	370	350	45	150	60	60	4.00	102.59
13	104	850	0.40	66.09	1.09	402.28	370	350	45	150	60	60	4.00	102.85
14	108	850	0.40	66.09	1.09	405.09	360	340	45	150	60	60	4.00	93.77
14	112	850	0.40	66.09	1.09	407.99	360	340	45	150	60	60	4.00	96.86

Table IV.26: Field Sampling Data for Test #6, Shell-Waterton, Traverse #1, October 7, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	820	0.02	14.61	0.05	407.99	370	210	50	70	50	50	0.50	0.00
1	4	820	0.02	14.61	0.05	408.64	370	250	50	70	50	50	0.50	97.25
1	8	820	0.06	25.30	0.16	409.70	375	280	50	70	50	50	0.80	91.85
2	12	820	0.06	25.30	0.16	410.81	375	300	50	100	50	50	0.80	95.72
2	16	820	0.20	46.20	0.55	413.07	375	330	50	110	50	50	1.50	107.60
3	20	830	0.20	46.38	0.56	415.30	375	340	50	130	60	60	1.50	103.97
3	24	830	0.30	56.80	0.83	417.80	375	350	50	140	60	60	2.50	95.37
4	28	830	0.30	56.80	0.83	420.32	375	350	50	150	60	60	2.50	96.49
4	32	840	0.38	64.17	1.05	423.28	375	360	40	160	60	60	3.00	100.63
5	36	840	0.38	64.17	1.05	426.07	375	350	40	160	60	60	3.00	95.35
5	40	840	0.38	64.17	1.05	429.20	370	350	40	140	60	60	3.00	106.38
6	44	840	0.40	65.84	1.10	432.21	370	350	40	140	60	60	3.00	100.10
6	48	840	0.42	67.47	1.16	435.39	370	350	40	140	60	60	4.00	103.15
7	52	850	0.42	67.73	1.16	438.40	370	350	40	140	60	60	4.00	98.01
7	56	850	0.42	67.73	1.16	441.46	370	350	40	140	60	60	4.00	99.66
8	60	850	0.42	67.73	1.16	444.40	370	350	40	140	60	60	4.00	95.81
8	64	850	0.44	69.32	1.20	447.48	370	340	40	150	60	60	4.00	97.93
9	68	850	0.44	69.32	1.20	450.79	370	340	40	150	60	60	4.20	105.23
9	72	850	0.44	69.32	1.20	453.62	380	350	40	150	60	60	4.20	90.06
10	76	850	0.44	69.32	1.20	456.55	380	350	40	150	60	60	4.20	93.21
10	80	850	0.44	69.32	1.20	459.97	380	340	40	150	60	60	4.20	108.69
11	84	850	0.44	69.32	1.20	462.90	380	340	40	140	60	60	4.20	93.24
11	88	850	0.44	69.32	1.20	466.08	380	340	40	140	60	60	4.20	101.24
12	92	850	0.44	69.32	1.20	469.49	380	340	40	140	60	60	4.20	108.27
12	96	850	0.44	69.32	1.20	472.58	380	340	40	140	60	60	4.20	98.38
13	100	850	0.44	69.32	1.20	475.59	380	340	40	140	60	60	4.20	95.85
13	104	850	0.44	69.32	1.20	479.04	380	330	40	140	60	60	4.20	109.68
14	108	850	0.44	69.32	1.20	482.04	380	320	40	140	60	60	4.20	95.39
14	112	850	0.44	69.32	1.20	485.35	380	310	40	140	60	60	4.20	105.18

Table IV.27: Field Sampling Data for Test #6, Shell-Waterton, Traverse #2, October 7, 1982.

Sample Analyses	Test No 6	Date	October 7/82		Waterton		
		Micrograms					
Sample From	P&N 6M HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concen-tration µg/rcf	Elemental Emission Rate g/hr
Volume (ml)	680	880	360	-	E_R = 1.9 x 10^4 kg/d (total)		
Total Particulate (mg)	39	6400		23	E_R = 1.8 x 10^2 kg/d (front end)		
Al Aluminum	140	88	110	$\boxed{50}$	$\boxed{380}$	$\boxed{3.7}$	$\boxed{46}$
As Arsenic	1.4	$\boxed{2.6}$	1.1	0.6	$\boxed{5.7}$	$\boxed{0.06}$	$\boxed{0.69}$
Cu Copper	$\boxed{27}$	$\boxed{12}$	11	10	$\boxed{60}$	$\boxed{0.6}$	$\boxed{7.3}$
Fe Iron	$\boxed{340}$	$\boxed{180}$	$\boxed{36}$	$\boxed{50}$	$\boxed{600}$	$\boxed{5.8}$	$\boxed{73}$
Sn Tin	140	$\boxed{530}$	36	50	$\boxed{750}$	$\boxed{7.2}$	$\boxed{91}$
Ti Tittanium	270	$\boxed{530}$	250	100	$\boxed{1200}$	$\boxed{11}$	$\boxed{140}$
Zn Zinc	$\boxed{61}$	$\boxed{62}$	$\boxed{36}$	$\boxed{15}$	$\boxed{170}$	$\boxed{1.7}$	$\boxed{21}$

All values excent those in boxes $\boxed{}$ are below the limit of detection

Table IV. 28 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell-Waterton Plant:
Test #6 Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: WATERTON

COMPANY: SHELL

2) TEST NO: 7 DATE: October 8, 1982

3) PRODUCTION: 2.56×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 25.19 (inches Hg)

STATIC PRESSURE: -2.9 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 15 1/8 (feet)

5) PITOT TUBE COEFFICIENT: 0.895

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 6.8, O_2 12.26, CO 0.0

SO_2 0.04, N_2 79.95, Ar 0.95

7) NO. OF READINGS: 56

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 14

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 304.1 (grams)

WATER CAUGHT BY DRYING AGENTS: 9.0 (grams)

MOISTURE CONTENT, B_{wo}: 0.105

9) MOLECULAR WEIGHT OF GAS:

29.76 DRY BASIS (lb_m/lb mole)

28.53 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 150.61 (acf)

11) AVERAGE STACK VELOCITY: 57.78 (ft/s); AVG. TEMP: 839 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 623000 (acfm)

TABLE IV.29 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	820	0.02	14.47	0.05	489.45	350	200	40	45	50	40	0.50	0.00
1	4	820	0.08	28.95	0.22	490.68	360	240	40	65	50	40	0.50	94.69
1	8	820	0.06	25.07	0.16	491.78	360	270	40	80	50	40	0.50	98.15
2	12	820	0.06	25.07	0.16	492.87	360	285	40	85	50	40	0.50	96.70
2	16	830	0.18	43.59	0.49	494.74	360	310	40	100	50	40	1.50	96.85
3	20	830	0.18	43.59	0.49	496.49	360	315	40	110	50	40	1.50	90.67
3	24	830	0.28	54.36	0.76	498.72	360	325	40	115	50	40	2.50	92.43
4	28	830	0.28	54.36	0.76	501.09	360	340	40	125	50	40	2.50	98.50
4	32	830	0.38	63.33	1.03	503.87	360	340	40	120	50	40	3.00	99.07
5	36	830	0.36	61.64	0.98	506.82	360	335	40	120	50	40	3.00	107.96
5	40	840	0.38	63.58	1.02	509.51	360	335	40	115	50	40	3.00	96.07
6	44	840	0.38	63.58	1.02	512.46	370	325	40	120	50	50	3.00	104.76
6	48	840	0.40	65.23	1.08	515.47	370	335	40	130	50	50	3.00	103.98
7	52	840	0.40	65.23	1.08	518.40	370	340	40	130	50	50	3.00	100.91
7	56	840	0.42	66.84	1.13	521.65	370	350	40	130	50	50	3.50	109.66
8	60	840	0.42	66.84	1.13	524.92	370	350	40	130	50	55	3.50	109.83
8	64	850	0.44	68.68	1.18	527.72	370	345	40	130	50	55	3.50	91.95
9	68	850	0.44	68.68	1.18	530.86	370	340	40	120	50	55	3.80	103.25
9	72	850	0.44	68.68	1.18	533.66	370	330	40	120	50	60	3.80	91.91
10	76	850	0.44	68.68	1.18	536.78	370	335	40	130	50	60	3.80	102.23
10	80	850	0.44	68.68	1.18	540.03	370	335	40	130	50	60	3.80	106.20
11	84	850	0.40	65.48	1.08	542.85	370	350	40	130	50	60	3.80	97.04
11	88	850	0.42	67.10	1.13	546.03	370	360	40	130	50	60	3.50	106.50
12	92	850	0.42	67.10	1.13	549.18	370	360	40	140	50	60	3.50	105.59
12	96	850	0.42	67.10	1.13	552.02	370	360	40	140	50	60	3.50	94.99
13	100	850	0.42	67.10	1.13	554.99	370	360	40	140	50	60	3.50	99.65
13	104	850	0.42	67.10	1.13	558.06	370	350	40	140	50	60	3.50	102.98
14	108	850	0.42	67.10	1.13	561.08	370	350	40	140	50	60	3.50	101.00
14	112	850	0.42	67.10	1.13	564.04	370	350	40	140	50	60	3.50	99.18

Test IV.30: Field Sampling Data for Test #7, Shell-Waterton, Traverse #1, October 8, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	820	0.04	20.47	0.11	564.04	360	210	45	70	50	55	0.50	0.00
1	4	820	0.04	20.47	0.11	565.02	360	260	45	90	50	55	0.50	106.10
1	8	820	0.04	20.47	0.11	566.00	360	300	55	100	50	60	0.50	103.94
2	12	820	0.04	20.47	0.11	567.02	360	310	55	100	60	60	0.50	108.81
2	16	820	0.14	38.29	0.39	568.74	360	330	50	130	60	60	1.50	97.30
3	20	830	0.14	38.44	0.39	570.57	360	340	50	135	60	60	1.50	104.49
3	24	830	0.26	52.39	0.72	572.76	360	350	50	135	60	60	2.50	91.25
4	28	830	0.26	52.39	0.72	575.32	360	355	50	150	60	60	2.50	107.03
4	32	830	0.30	56.27	0.83	577.91	360	350	50	150	60	60	3.00	100.87
5	36	830	0.30	56.27	0.83	580.52	360	345	50	150	60	60	3.00	101.89
5	40	830	0.36	61.64	1.00	583.44	360	345	50	150	60	60	3.50	103.50
6	44	830	0.36	61.64	1.00	586.36	360	340	50	160	60	60	3.50	103.97
6	48	840	0.40	65.23	1.10	589.08	370	340	50	180	60	60	4.00	92.31
7	52	840	0.40	65.23	1.10	591.98	370	330	50	180	60	60	4.00	98.05
7	56	840	0.42	66.84	1.16	594.93	370	335	50	180	60	60	4.30	97.52
8	60	840	0.42	66.84	1.16	598.03	365	340	50	160	60	60	4.30	102.61
8	64	850	0.42	67.10	1.16	601.01	365	345	50	160	65	65	4.30	98.05
9	68	850	0.42	67.10	1.16	604.20	370	340	50	150	65	65	4.30	104.77
9	72	850	0.42	67.10	1.17	607.46	360	345	60	150	70	70	4.30	106.19
10	76	850	0.42	67.10	1.17	610.35	360	345	60	150	70	70	4.30	94.18
10	80	850	0.48	71.73	1.33	613.94	360	350	60	150	70	70	6.00	109.29
11	84	850	0.48	71.73	1.33	617.49	370	350	60	160	70	70	6.00	108.16
11	88	850	0.46	70.22	1.28	620.87	380	355	50	170	70	70	6.00	105.31
12	92	850	0.46	70.22	1.28	624.03	380	355	50	170	70	70	6.50	98.45
12	96	850	0.46	70.22	1.28	627.34	380	350	50	170	70	70	6.50	102.90
13	100	850	0.46	70.22	1.28	630.27	370	350	50	170	70	70	6.50	91.29
13	104	850	0.46	70.22	1.28	633.54	370	350	50	170	70	70	6.50	101.65
14	108	850	0.46	70.22	1.28	637.02	370	350	50	170	70	70	5.00	108.31
14	112	850	0.46	70.22	1.28	640.07	370	345	50	170	70	70	5.00	94.97

Table IV.31: Field Sampling Data for Test #7, Shell-Waterton, Traverse #2, October 8, 1982.

Sample Analyses Test No 7 Date Octover 8/82 Waterton

Sample From	P&N 6M HNO_3	Micrograms IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concen-tration µg/rcf	Elemental Emission Rate g/hr
Volume (ml)	600	850	375	-	$E_R = 2.2 \times 10^4$ kg/d (total)		
Total Particulate (mg)	36	7400	-	38	$E_R = 2.2 \times 10^2$ kg/d (front end)		
Al Aluminum	120	85	110	$\boxed{100}$	$\boxed{420}$	$\boxed{4}$	$\boxed{52}$
Cu Copper	$\boxed{12}$	8.5	$\boxed{20}$	10	$\boxed{52}$	$\boxed{0.50}$	$\boxed{6.4}$
Fe Iron	$\boxed{180}$	$\boxed{340}$	$\boxed{75}$	$\boxed{50}$	$\boxed{650}$	$\boxed{6.2}$	$\boxed{79}$
Ge Germanium	120	85	110	$\boxed{100}$	$\boxed{420}$	$\boxed{4.0}$	$\boxed{52}$
Sb Antimony	$\boxed{48}$	51	38	20	$\boxed{160}$	$\boxed{1.5}$	$\boxed{19}$
Zn Zinc	$\boxed{66}$	$\boxed{43}$	$\boxed{38}$	$\boxed{15}$	$\boxed{160}$	$\boxed{1.5}$	$\boxed{20}$

All values except those in boxes ☐ are below the limit of detection

Table IV. 32 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Shell-Waterton Plant:
Test #7 Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD
LOCATION: PINCHER CREEK
COMPANY: GULF

2) TEST NO: Prelim DATE: October 9, 1982

3) PRODUCTION: 0.404×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)
STATIC PRESSURE: -2.4 (inches H_2O)
STACK DIMENSIONS: DIAMETER (D) 4 1/4 (feet)

5) PITOT TUBE COEFFICIENT: 0.895
METER CORRECTION FACTOR: 1.0
NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)
CO_2 1.00, O_2 16.70, CO 0.0
SO_2 0.28, N_2 81.06, Ar 0.96

7) NO. OF READINGS: 40
TIME BETWEEN READINGS: 4 min.
TEST POINTS/TRAVERSE: 10
NO. OF TRAVERSES: 2

8) CONDENSED WATER: 192.1 (grams)
WATER CAUGHT BY DRYING AGENTS: 6.0 (grams)
MOISTURE CONTENT, B_{wo}: 0.115

9) MOLECULAR WEIGHT OF GAS:
29.69 DRY BASIS (lb_m/lb mole)
28.35 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 86.97 (acf)

11) AVERAGE STACK VELOCITY: 60. (ft/s) AVG. TEMP: 1160 (°F)
AVERAGE VOLUMETRIC FLOW RATE: 50900 (acfm)

TABLE IV. 33 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	1150	0.26	59.03	0.67	671.71	490	230	40	75	50	50	2.50	0.00
1	4	1150	0.30	63.41	0.77	673.79	510	270	40	110	50	50	2.50	92.28
1	8	1150	0.30	63.41	0.78	675.87	510	310	40	120	60	50	2.50	91.35
2	12	1150	0.32	65.49	0.84	678.17	510	315	40	125	60	50	2.80	98.13
2	16	1155	0.36	69.57	0.94	680.83	510	315	40	145	60	55	3.00	106.61
3	20	1155	0.36	69.57	0.94	683.27	510	315	40	150	65	60	3.00	96.47
3	24	1155	0.36	69.57	0.94	685.77	510	320	40	160	65	60	3.00	99.26
4	28	1160	0.34	67.71	0.89	688.41	510	320	40	170	65	65	3.00	107.36
4	32	1160	0.34	67.71	0.90	690.64	510	330	40	170	70	60	2.80	90.73
5	36	1160	0.34	67.71	0.90	693.07	510	330	40	170	70	65	2.80	98.23
5	40	1160	0.32	65.69	0.84	695.30	510	330	40	170	70	70	2.50	92.73
6	44	1160	0.32	65.69	0.84	697.53	510	330	40	170	70	70	2.50	92.29
6	48	1165	0.30	63.70	0.79	699.84	500	330	40	170	70	70	2.30	99.21
7	52	1165	0.30	63.70	0.79	702.28	460	335	40	175	70	70	2.30	104.62
7	56	1170	0.28	61.64	0.73	704.41	460	330	40	175	70	70	2.00	94.77
8	60	1170	0.28	61.64	0.73	706.81	400	330	40	175	70	70	2.00	107.06
8	64	1170	0.22	54.64	0.58	708.99	400	330	45	170	70	70	1.80	109.37
9	72	1170	0.22	54.64	0.58	710.84	400	330	45	160	70	70	1.80	92.61
9	76	1170	0.12	40.35	0.31	712.18	400	330	45	160	70	65	1.00	91.34
10	76	1170	0.12	40.35	0.31	713.56	400	330	45	150	70	65	1.00	94.40
10	80	1170	0.12	40.35	0.31	715.09	400	330	45	150	70	65	1.00	104.43

Table IV.34: Field Sampling Data for Preliminary Survey, Gulf-Pincher Creek, Traverse #1, October 9, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1150	0.32	65.49	0.84	715.09	480	170	50	90	60	60	2.80	0.00
1	4	1150	0.32	65.49	0.84	717.39	480	220	50	110	60	60	2.80	96.87
1	8	1150	0.32	65.49	0.84	719.79	490	250	50	125	60	60	3.00	101.36
2	12	1150	0.32	65.49	0.84	722.07	490	300	45	140	60	60	3.00	96.23
2	16	1155	0.36	69.57	0.94	724.71	500	350	45	160	60	60	3.00	105.09
3	20	1155	0.38	71.48	1.00	727.41	500	350	45	165	60	60	3.00	104.48
3	24	1155	0.36	69.57	0.94	729.94	510	350	50	175	60	60	3.00	101.11
4	28	1160	0.36	69.68	0.93	732.61	510	350	50	180	60	60	3.00	106.28
4	32	1160	0.36	69.68	0.94	735.32	510	360	50	180	65	60	3.00	107.65
5	36	1160	0.36	69.68	0.94	738.07	510	360	50	180	65	60	3.00	109.38
5	40	1160	0.30	63.61	0.79	740.56	480	350	50	180	65	65	2.50	107.44
6	44	1165	0.30	63.70	0.79	742.87	470	350	50	180	65	65	2.50	100.13
6	48	1170	0.30	63.80	0.79	745.04	450	340	50	180	70	65	2.50	93.77
7	52	1170	0.30	63.80	0.79	747.39	440	340	50	180	70	65	2.50	101.52
7	56	1170	0.30	63.80	0.79	749.83	435	340	50	180	70	70	2.50	105.14
8	60	1170	0.30	63.80	0.79	752.09	420	340	50	180	70	70	2.50	97.17
8	64	1170	0.20	52.09	0.52	753.93	420	330	50	175	70	70	2.50	96.69
9	68	1170	0.20	52.09	0.52	755.94	410	335	50	175	70	70	2.50	105.61
9	72	1170	0.04	23.30	0.52	756.82	400	330	55	150	70	70	1.00	103.41
10	76	1170	0.04	23.30	0.52	757.75	390	330	55	150	70	70	1.00	109.96
10	80	1170	0.04	23.30	0.52	758.68	390	330	55	150	70	70	1.00	109.07

Table IV.35 : Field Sampling Data for Preliminary Survey, Gulf-Pincher Creek, Traverse #2, October 9, 1982.

Sample Analyses	Test No	Prelim	Date	October 9/82		Pincher Creek	
		Micrograms					
Sample From	P&N 6M HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
Volume (ml)	570	770	310	-	$E_R = 7.2 \times 10^3$ kg/d (total)		
Total Particulate (mg)	39	24000	-	22	$E_R = 2.2 \times 10^1$ kg/d (front end)		
Al Aluminum	$\boxed{170}$	150	93	$\boxed{100}$	$\boxed{520}$	$\boxed{7.7}$	$\boxed{6.5}$
Cu Copper	$\boxed{200}$	15	9.3	10	$\boxed{230}$	$\boxed{3.5}$	$\boxed{2.9}$
Fe Iron	$\boxed{110}$	$\boxed{23}$	$\boxed{62}$	$\boxed{20}$	$\boxed{220}$	$\boxed{3.3}$	$\boxed{2.7}$
Sb Antimony	$\boxed{57}$	54	31	20	$\boxed{160}$	$\boxed{2.4}$	$\boxed{2.0}$
Ti Titanium	$\boxed{170}$	$\boxed{230}$	93	60	$\boxed{560}$	$\boxed{8.3}$	$\boxed{6.9}$
Zn Zinc	$\boxed{63}$	$\boxed{15}$	$\boxed{43}$	$\boxed{14}$	$\boxed{140}$	$\boxed{2.0}$	$\boxed{1.7}$

All values except those in boxes ☐ are below the limit of detection

Tabe IV. 36 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Gulf-Pincher Creek Plant:
Preliminary Survey Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: PINCHER CREEK

COMPANY: GULF

2) TEST NO: 1 DATE: October 10, 1982

3) PRODUCTION: 0.407×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)

STATIC PRESSURE: -2.5 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 4 1/4 (feet)

5) PITOT TUBE COEFFICIENT: 0.895

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 1.45 , O_2 17.45, CO 0.0

SO_2 0.53 , N_2 79.62, Ar 0.95

7) NO. OF READINGS: 40

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 10

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 162.7 (grams)

WATER CAUGHT BY DRYING AGENTS: 5.9 (grams)

MOISTURE CONTENT, B_{wo}: 0.105

9) MOLECULAR WEIGHT OF GAS:

29.87 DRY BASIS (lb_m/lb mole)

28.62 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 88.15 (acf)

11) AVERAGE STACK VELOCITY: 59 (ft/s) AVG. TEMP: 1160 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 50600 (acfm)

TABLE IV.37 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
							PROBE	OVEN	IMPINGERS OUTLET	IMPINGERS INLET	GAS METER OUT	GAS METER IN		
0	0	1150	0.30	63.11	0.77	778.78	520	170	50	75	50	50	2.00	0.00
1	4	1150	0.32	65.18	0.82	780.93	520	240	45	90	50	50	2.00	91.48
1	8	1155	0.34	67.29	0.87	783.31	520	260	45	110	50	50	2.50	98.95
2	12	1155	0.34	67.29	0.87	785.48	520	300	45	110	50	50	2.50	90.27
2	16	1155	0.34	67.29	0.87	787.68	520	340	45	165	50	50	2.50	91.10
3	20	1155	0.36	69.24	0.92	790.01	520	350	45	175	50	50	2.50	94.14
3	24	1160	0.38	71.25	0.98	792.71	520	350	45	180	60	55	3.00	104.91
4	28	1160	0.38	71.25	0.98	795.35	520	350	45	185	60	55	3.00	102.18
4	32	1160	0.38	71.25	0.98	798.16	520	360	45	180	60	55	3.00	108.92
5	36	1165	0.38	71.36	0.99	800.62	520	365	45	200	65	70	3.00	93.79
5	40	1170	0.32	65.58	0.84	803.08	520	370	45	210	65	70	2.50	102.50
6	44	1170	0.32	65.58	0.84	805.28	520	365	45	200	70	70	2.50	90.84
6	48	1170	0.32	65.58	0.84	807.76	500	350	50	200	70	70	2.50	102.59
7	52	1170	0.32	65.58	0.84	810.12	495	345	50	200	70	70	2.50	97.90
7	56	1170	0.28	61.35	0.73	812.48	480	330	50	195	70	70	2.00	104.09
8	60	1170	0.28	61.35	0.73	814.83	470	330	50	190	70	75	2.00	103.41
8	64	1170	0.20	51.85	0.52	816.82	465	340	55	190	70	75	1.50	103.59
9	68	1170	0.20	51.85	0.52	818.56	440	340	55	155	70	75	1.50	90.87
9	72	1170	0.04	23.19	0.10	819.36	430	335	55	140	70	75	1.00	92.87
10	76	1170	0.04	23.19	0.10	820.22	410	330	55	135	70	75	1.00	99.43
10	80	1170	0.04	23.19	0.10	821.09	390	325	55	130	70	75	1.00	100.65

Table IV.38: Field Sampling Data for Test No. #1, Gulf-Pincher Creek, Traverse #1, October 10, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1150	0.30	63.11	0.80	821.09	480	220	50	85	70	70	2.50	0.00
1	4	1150	0.28	60.97	0.76	823.61	495	280	45	125	80	80	2.50	108.93
1	8	1150	0.32	65.18	0.87	826.27	495	320	45	130	80	80	2.80	107.54
2	12	1155	0.34	67.29	0.92	828.95	500	330	45	130	80	80	3.00	104.92
2	16	1155	0.36	69.24	0.97	831.62	480	340	45	155	80	80	3.00	101.65
3	20	1155	0.32	65.28	0.86	834.23	480	380	45	160	80	80	2.50	105.58
3	24	1160	0.36	69.35	0.97	836.81	500	375	45	170	80	80	3.00	98.67
4	28	1160	0.36	69.35	0.97	839.49	490	360	45	170	80	85	3.00	101.71
4	32	1165	0.34	67.50	0.92	842.11	490	345	45	170	85	85	3.00	102.21
5	36	1165	0.34	67.50	0.92	844.62	490	340	45	175	85	85	3.00	97.87
5	40	1170	0.30	63.50	0.81	847.20	480	340	45	175	85	85	2.50	107.29
6	44	1170	0.28	61.35	0.76	849.59	480	335	45	180	85	85	2.50	102.84
6	48	1170	0.30	63.50	0.81	851.89	470	340	45	180	85	90	2.50	91.44
7	52	1170	0.30	63.50	0.82	854.31	470	350	50	180	90	90	2.50	103.00
7	56	1170	0.28	61.35	0.76	856.54	455	350	50	185	90	90	2.00	95.06
8	60	1170	0.28	61.35	0.76	858.96	450	345	50	190	90	90	2.00	103.30
8	64	1165	0.20	51.77	0.55	861.03	440	345	50	190	90	90	1.50	104.25
9	68	1165	0.20	51.77	0.55	862.94	430	340	50	180	90	90	2.00	95.79
9	72	1160	0.10	36.55	0.27	864.29	410	340	50	170	90	90	1.00	96.43
10	76	1160	0.10	36.55	0.27	865.65	410	340	50	170	90	90	1.00	96.46
10	80	1160	0.10	36.55	0.27	866.93	410	330	50	160	90	90	1.00	90.81

Test IV.39: Field Sampling Data for Test No.#1, Gulf-Pincher Creek, Traverse #2, October 10, 1982.

Sample Analyses Test No 1 Date October 10/82 Pincher Creek

Sample From	P&N 6M HNO_3		Micrograms		Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
		IMP. 1,2,3,	IMP. 4,5	Filter			
Volume (ml)	605	895	355	-	$E_R = 1.1 \times 10^4$ kg/d (total)		
Total Particulate (mg)	20	38000	-	34	$E_R = 1.6 \times 10^1$ kg/d (front end)		
Al Aluminum	240	$\boxed{360}$	110	$\boxed{100}$	$\boxed{810}$	$\boxed{14}$	$\boxed{11}$
Cd Cadmium	$\boxed{2.4}$	2.7	2.5	2.0	$\boxed{9.6}$	$\boxed{0.17}$	$\boxed{0.14}$
Cu Copper	$\boxed{61}$	9.0	11	10	$\boxed{90}$	$\boxed{1.2}$	$\boxed{1.3}$
Fe Iron	$\boxed{240}$	$\boxed{90}$	$\boxed{32}$	$\boxed{20}$	$\boxed{380}$	$\boxed{5.6}$	$\boxed{5.4}$
Li Lithium	$\boxed{1.2}$	0.90	1.1	0.6	$\boxed{3.8}$	$\boxed{0.07}$	$\boxed{0.05}$
Ti Titanium	$\boxed{120}$	$\boxed{360}$	$\boxed{110}$	60	$\boxed{650}$	$\boxed{11}$	$\boxed{9.1}$
Zn Zinc	-	$\boxed{54}$	$\boxed{11}$	$\boxed{20}$	$\boxed{85}$	$\boxed{1.5}$	$\boxed{1.2}$

All values except those in boxes ☐ are below the limit of detection

Table IV. 40 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Gulf-Pincher Creek Plant:
Test #1 Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: PINCHER CREEK

COMPANY: GULF

2) TEST NO: 2 DATE: October 10, 1982

3) PRODUCTION: 0.390×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)

STATIC PRESSURE: -2.5 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D)4 1/4 (feet)

5) PITOT TUBE COEFFICIENT: 0.895

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 6.62, O_2 13.43, CO 0.05

SO_2 0.40, N_2 78.57, Ar 0.93

7) NO. OF READINGS: 40

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 10

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 212.4 (grams)

WATER CAUGHT BY DRYING AGENTS: 5.5 (grams)

MOISTURE CONTENT, B_{wo}: 0.128

9) MOLECULAR WEIGHT OF GAS:

30.01 DRY BASIS (lb_m/lb mole)

28.47 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 84.31 (acf)

11) AVERAGE STACK VELOCITY: 59 (ft/s) AVG. TEMP: 1160 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 49900 (acfm)

TABLE IV.41 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1150	0.28	61.14	0.61	889.72	500	190	60	95	60	60	1.00	0.00
1	4	1150	0.28	61.14	0.61	891.82	500	245	55	95	60	60	1.00	96.54
1	8	1155	0.34	67.48	0.75	894.02	500	255	50	100	60	60	2.00	91.63
2	12	1155	0.34	67.48	0.75	896.41	500	320	50	130	60	60	2.00	99.76
2	16	1155	0.34	67.48	0.75	898.66	500	325	50	140	60	60	2.00	93.93
3	20	1155	0.36	69.43	0.81	901.32	500	350	50	140	70	70	2.00	105.74
3	24	1160	0.34	67.58	0.77	903.98	500	360	55	160	70	70	2.00	109.02
4	28	1160	0.34	67.58	0.77	906.48	500	360	55	180	70	70	2.00	102.47
4	32	1160	0.34	67.58	0.77	908.80	500	345	60	175	75	80	2.00	93.64
5	36	1165	0.34	67.68	0.77	911.26	500	330	60	170	75	80	2.00	99.60
5	40	1170	0.32	65.76	0.72	913.53	500	330	60	170	75	80	2.00	94.85
6	44	1170	0.32	65.76	0.73	915.76	460	330	60	165	80	80	2.00	92.70
6	48	1170	0.30	63.68	0.68	918.15	450	330	60	170	80	80	1.80	102.48
7	52	1170	0.30	63.68	0.68	920.49	445	330	60	170	80	80	1.80	100.56
7	56	1170	0.30	63.68	0.68	922.84	440	330	60	170	80	80	1.80	101.02
8	60	1170	0.30	63.68	0.68	925.20	430	330	65	160	80	80	1.80	101.12
8	64	1165	0.16	46.43	0.36	926.86	430	330	65	150	80	80	1.00	97.44
9	68	1160	0.16	46.36	0.36	928.47	420	330	70	150	80	80	1.00	94.56
9	72	1160	0.04	23.18	0.09	929.25	410	325	70	145	80	80	0.80	90.40
10	76	1160	0.04	23.18	0.09	930.03	410	320	70	140	80	80	0.80	91.37
10	80	1160	0.04	23.18	0.09	930.83	410	320	70	140	80	80	0.80	94.45

Table IV.42: Field Sampling Data for Test No. #2, Gulf-Pincher Creek, Traverse #1, October 10, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	T E M P E R A T U R E S (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1155	0.26	59.01	0.60	930.83	510	200	50	85	75	75	1.50	0.00
1	4	1155	0.26	59.01	0.60	933.09	530	280	50	100	75	75	1.50	104.44
1	8	1155	0.30	63.38	0.68	935.32	530	310	50	110	75	75	2.00	96.48
2	12	1155	0.36	69.43	0.82	937.83	530	350	50	155	75	75	2.00	98.86
2	16	1160	0.36	69.54	0.82	940.49	530	350	50	180	75	75	2.00	104.75
3	20	1160	0.36	69.54	0.82	942.99	530	340	50	190	75	75	2.00	98.81
3	24	1165	0.36	69.65	0.82	945.29	530	335	50	190	80	80	2.00	90.06
4	28	1165	0.36	69.65	0.82	947.62	530	335	50	190	80	80	2.50	91.07
4	32	1165	0.36	69.65	0.82	950.07	530	330	50	190	80	80	2.50	95.77
5	36	1165	0.36	69.65	0.82	952.49	530	325	50	190	80	80	2.50	95.04
5	40	1170	0.32	65.76	0.73	955.10	510	325	50	190	80	80	2.00	108.32
6	44	1170	0.32	65.76	0.73	957.37	510	325	50	190	80	80	2.00	94.46
6	48	1170	0.32	65.76	0.73	959.58	500	320	50	190	80	80	2.00	91.92
7	52	1165	0.30	63.58	0.69	961.97	480	320	50	190	85	85	2.00	101.36
7	56	1165	0.30	63.58	0.69	964.34	460	320	50	190	85	85	2.00	100.86
8	60	1165	0.30	63.58	0.69	966.53	450	320	55	190	85	85	2.00	92.94
8	64	1165	0.16	46.43	0.37	968.42	435	320	55	180	85	85	1.00	109.91
9	68	1165	0.16	46.43	0.37	970.19	475	315	55	170	85	85	1.00	102.90
9	72	1165	0.08	32.83	0.18	971.51	410	310	55	160	85	85	0.80	108.17
10	76	1160	0.08	32.78	0.18	972.76	410	310	60	145	85	85	0.80	102.89
10	80	1160	0.08	32.78	0.18	974.03	400	310	60	140	85	85	0.80	103.84

Table IV.43 : Field Sampling Data for Test No. #2, Gulf-Pincher Creek, Traverse #2, October 10, 1982.

Sample Analyses   Test No 2   Date October 10/82   Pincher Creek

Sample From	P&N 6M HNO_3	IMP. 1,2,3,	IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/rcf	Elemental Emission Rate g/hr
	Micrograms						
Volume (ml)	715	840	430	-	$E_R = 1.1 \times 10^3$ kg/d (total)		
Total Particulate (mg)	51	-	-	24	$E_R = 2.4 \times 10^1$ kg/d (front end)		
Al Aluminum	$\boxed{140}$	$\boxed{84}$	$\boxed{130}$	$\boxed{200}$	$\boxed{560}$	$\boxed{8.1}$	$\boxed{6.7}$
Cu Copper	$\boxed{36}$	8.4	13	10	$\boxed{67}$	$\boxed{0.98}$	$\boxed{0.81}$
Fe Iron	$\boxed{140}$	$\boxed{59}$	$\boxed{34}$	$\boxed{30}$	$\boxed{270}$	$\boxed{3.9}$	$\boxed{3.2}$
Ti Ttanium	$\boxed{220}$	$\boxed{250}$	$\boxed{130}$	60	$\boxed{660}$	$\boxed{9.6}$	$\boxed{7.9}$
Zn Zinc	$\boxed{36}$	$\boxed{25}$	$\boxed{13}$	$\boxed{18}$	$\boxed{92}$	$\boxed{1.3}$	$\boxed{1.1}$

All values except those in boxes ☐ are below the limit of detection

Table IV. 44 Summary of Incinerator Stack Source Sampling Data for Elements Whose Presence was Detected at the Gulf-Pincher Creek Plant:
Test #2 Glass Liner

1) CLIENT NAME: ENERGY RESOURCES CONSERVATION BOARD

LOCATION: PINCHER CREEK

COMPANY: GULF

2) TEST NO: 3 DATE: October 11, 1982

3) PRODUCTION: 0.391×10^6 m^3/day Plant Sales

4) BAROMETRIC PRESSURE: 24.89 (inches Hg)

STATIC PRESSURE: -2.4 (inches H_2O)

STACK DIMENSIONS: DIAMETER (D) 4 1/4 (feet)

5) PITOT TUBE COEFFICIENT: 0.895

METER CORRECTION FACTOR: 1.0

NOZZLE DIAMETER: 0.3125 (inches)

6) GAS COMPOSITION: (percent by volume)

CO_2 8.03, O_2 12.39, CO 0.0

SO_2 0.38, N_2 78.26, Ar 0.94

7) NO. OF READINGS: 40

TIME BETWEEN READINGS: 4 min.

TEST POINTS/TRAVERSE: 10

NO. OF TRAVERSES: 2

8) CONDENSED WATER: 69.5 (grams)

WATER CAUGHT BY DRYING AGENTS: 4.7 (grams)

MOISTURE CONTENT, B_{wo}: 0.044

9) MOLECULAR WEIGHT OF GAS;

29.97 DRY BASIS (lb_m/lb mole)

29.44 WET BASIS (lb_m/lb mole)

10) VOLUME OF GAS SAMPLED: 92.10 (acf)

11) AVERAGE STACK VELOCITY: 57 (ft/s) AVG. TEMP: 1160 (°F)

AVERAGE VOLUMETRIC FLOW RATE: 48800 (acfm)

TABLE IV. 45 FIELD DATA SUMMARY SHEET

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1150	0.28	60.11	0.63	5.51	510	165	45	75	65	65	1.80	0.00
1	4	1150	0.28	60.11	0.63	7.69	510	230	45	80	65	65	1.80	91.76
1	8	1150	0.34	66.24	0.76	10.32	520	295	45	120	65	65	2.00	100.58
2	12	1155	0.34	66.34	0.77	12.90	520	300	45	120	70	70	2.00	97.59
2	16	1155	0.36	68.26	0.81	15.62	530	340	45	140	70	70	2.20	100.37
3	20	1155	0.36	68.26	0.81	18.44	530	350	45	150	70	70	2.20	103.90
3	24	1160	0.34	66.44	0.77	21.09	530	340	45	160	75	75	2.00	100.03
4	28	1160	0.34	66.44	0.77	23.89	530	340	45	170	75	75	2.00	105.09
4	32	1160	0.34	66.44	0.77	26.28	530	345	45	175	75	75	2.00	90.29
5	36	1160	0.34	66.44	0.77	28.83	530	350	45	180	75	75	2.00	95.92
5	40	1165	0.32	64.56	0.72	31.48	530	350	45	180	75	75	2.00	102.91
6	44	1165	0.30	62.51	0.68	33.83	530	340	45	185	75	75	1.60	94.11
6	48	1165	0.30	62.51	0.68	36.28	530	340	45	185	75	75	1.60	98.53
7	52	1170	0.32	64.66	0.72	38.96	490	335	45	185	75	75	2.00	101.16
7	56	1170	0.26	58.28	0.59	41.24	485	340	45	185	75	75	2.00	98.15
8	60	1170	0.30	62.60	0.68	43.51	470	345	45	190	75	75	2.00	91.48
8	64	1165	0.22	53.53	0.50	45.79	450	345	45	190	80	80	1.80	105.54
9	68	1165	0.22	53.53	0.50	48.16	450	345	45	190	80	80	1.80	109.96
9	72	1160	0.14	42.64	0.32	50.05	440	350	50	190	80	80	1.00	109.85
10	76	1160	0.14	42.64	0.32	51.94	420	350	50	190	80	80	1.00	109.49
10	80	1160	0.14	42.64	0.32	53.80	415	350	50	190	80	80	1.00	108.24

Table IV.46: Field Sampling Data for Test No.#3, Gulf-Pincher Creek, Traverse #1, October 11, 1982.

SAMPLE POINT (NO)	TIME (MIN)	STACK TEMP DEG.F	DELTA P (IN H2O)	VEL (FT/S)	DELTA H (IN H2O)	GAS METER VOLUME (CUFT)	TEMPERATURES (DEG.F)						PUMP VAC (IN HG)	ISOKINETIC VARIATION (PERCENT)
									IMPINGERS		GAS METER			
							PROBE	OVEN	OUTLET	INLET	OUT	IN		
0	0	1155	0.26	58.01	0.60	53.80	530	210	55	100	80	80	1.50	0.00
1	4	1155	0.26	58.01	0.60	56.25	530	240	55	115	80	80	1.50	104.05
1	8	1155	0.30	62.32	0.69	58.52	530	305	50	135	80	80	2.00	90.17
2	12	1155	0.30	62.32	0.69	61.16	530	345	50	135	80	80	2.00	104.59
2	16	1160	0.34	66.44	0.78	63.74	530	350	50	150	80	80	2.00	95.98
3	20	1160	0.34	66.44	0.78	66.27	530	345	50	155	80	80	2.00	94.55
3	24	1165	0.32	64.56	0.73	68.96	520	345	50	150	80	80	2.00	103.46
4	28	1165	0.32	64.56	0.74	71.84	520	340	50	150	85	85	1.80	109.83
4	32	1165	0.32	64.56	0.74	74.67	510	340	50	150	85	85	1.80	107.88
5	36	1165	0.30	62.51	0.69	77.18	510	320	50	150	85	85	1.70	98.75
5	40	1165	0.26	58.19	0.60	79.58	500	320	50	150	85	85	1.70	101.63
6	44	1170	0.26	58.28	0.60	81.96	490	350	55	150	85	85	1.70	100.99
6	48	1170	0.28	60.48	0.64	84.20	480	345	50	170	85	85	2.00	91.28
7	52	1170	0.28	60.48	0.64	86.62	470	340	50	175	85	85	2.00	98.73
7	56	1170	0.26	58.28	0.60	88.76	460	340	50	180	85	85	2.00	90.85
8	60	1170	0.26	58.28	0.60	91.04	445	340	55	185	85	85	2.00	96.53
8	64	1170	0.16	45.72	0.37	92.92	430	340	60	185	85	85	1.00	101.55
9	68	1165	0.16	45.65	0.37	94.79	415	340	60	175	85	85	1.00	100.55
9	72	1165	0.04	22.82	0.09	95.80	405	340	60	155	85	85	0.50	109.37
10	76	1160	0.04	22.79	0.09	96.65	380	330	60	140	85	85	0.50	91.23
10	80	1160	0.04	22.79	0.09	97.61	370	330	60	130	85	85	0.50	103.08

Test IV.47 : Field Sampling Data for Test No.#3, Gulf-Pincher Creek, Traverse #2, October 11, 1982.

APPENDIX V

PLANT OPERATING DATA

Variable Test	Prel 1982 9/4	1 1982 9/5	2 1982 9/6	3 1982 9/7	4 1982 9/8	5 1982 10/6	6 1982 10/7	7 1982 10/8
Total Plant Intake 10^6 m^3/day	4.72	4.73	4.69	4.70	5.01	4.52	4.40	4.54
Total Plant Sales Gas 10^6 m^3/day	2.56	2.61	2.61	2.53	2.73	2.36	2.39	2.56
Total Acid Gas 10^3 m^3/day	1.03	1.03	1.04	1.03	1.10	1.16	1.10	1.07
Flared Gas 10^3 m^3/day	0	0	0	0	0	0	0	0
Stack Volumetric Flow Rate, 68°F, dry 10^6 m^3/day	8400	8300	8200	7700	8100	8600	8600	9000
Sulphur Emissions t/day	6.0	6.0	4.6	4.3	7.3	10.1	10.0	11.2
Stack Gas Temperature Top, °C	440	436	432	431	434	435	463	441
Stack Gas Temperature 45.7m, °C	463	465	461	461	469	467	466	472
Avg. Sulphur Concentration Incinerator Stack, %	0.047	0.053	0.03	0.03	-	-	-	-

Table V.1 Plant Operating Data at Shell Canada Resources, Waterton Gas Plant

Variables Test	Prel 1982 10 9	1 1982 10 10	2 1982 10 10	3 1982 10 11
Total Plant Intake $10^6 m^3$/day	0.517	0.520	0.501	0.504
Total Plant Sales Gas $10^6 m^3$/day	0.404	0.407	0.394	0.391
Total Acid Gas $10^6 m^3$/day	0.056	0.060	0.061	0.060
Flared Gas 10^3m/day	0	0	0	0
Stack Volumetric Flow Rate 60°F, wet; $10^3 m^3$/day	692	677	666	673
Sulphur Emissions t/day	2.82	2.94	2.83	2.72
Stack Gas Temperature Top, °C	547	548	545	550
Stack Gas Temperature MIddle, °C	628	630	625	625
Average Sulphur Concentration Incinerator Stack, %	0.36	0.38	0.38	0.35

Table V.2 Plant Operating Data at Pincher Creek - Gulf Oil Canada Limited

APPENDIX VI

PROCEDURE FOR ESTIMATING MAXIMUM POSSIBLE EMISSION RATES OF ALL ELEMENTS OF INTEREST

APPENDIX VI.

Tables VI.1 and VI.8 summarize the maximum possible emission rates of each of the elements for 2 independent source sampling tests carried out with borosilicate glass lined probes at the Shell-Waterton Gas Plant. Maximum possible elemental emission rates determined for 3 independent source sampling tests with a borosilicate glass lined probe at the Gulf-Pincher Creek Gas Plant are listed in Tables VI.9 to VI.11. Figures VI.1 to VI.3 illustrate the maximum mean emission rates and the corresponding ranges for the elements at the 2 plants.

For elements whose presence could not be detected in any part (probe, filter, impingers, cold trap) of the sampling train because their ultimate liquid concentrations for analysis were below the instrumental limits of detection, individual test and mean maximum possible emission rates were estimated by assuming presence at the limits of detection (LOD) values. In Figures VI.1 to VI.3, such mean emission rates are represented by open circles.

Emission rates of elements whose presence was detected, in at least one of the 4 samples recovered from the sampling train parts after each test, were evaluated from measured and limit of detection concentrations. These rates are depicted by solid circles. Open circles below the solid ones provide measures of mean maximum possible emission rates corresponding to LOD values only.

In Figures VI.1 to VI.3 all mean emission rates are bracketed to indicate the upper and lower bounds of measured or LOD magnitudes for each element under consideration.

An examination of Tables VI.1 to VI.11 and Figures VI.1 to VI.3 suggests that there is a definite need to distinguish clearly between elements whose presence was "detected" and those whose presence was "established".

An element has been classified as "detected" if an ultimate analysis solution absorbance exceeded the value corresponding to the LOD concentration as well as the laboratory blank values for that species at least once. On the other hand, the presence of an element was "established" if that element was "detected" in more than one-half of the tests or at a concentration 3 times the limit of detection (LOD).

An appreciation of the difference between a "detected" and an "established" presence of an element can be realized in terms of the values in Table VI.1 and Tables VI.5 to VI.8, pertaining to the determination of arsenic. The summary of pertinent data in Table VI.12 shows that the presence of arsenic was "detected" only once (2.6 ug in Impingers 1, 2, 3; Test #6) during analysis of the 4 samples recovered from the sampling train, after each of the 5 independent tests with the borosilicate-glass lined probe.

Sample Analyses Test no. Prelim Date September 4,/82

Sample From	Pm & Pr HNO3	IMP. 1,2,3,	Silicone IMP. 4,5	Filter	Total Elemental Weight µg	Maximum Possible Elemental Concentration µg/m³	Elemental Emission Rate g /hr
Volume (ml)	440	410	130	-	$Q_s = 1.6 \times 10^4$ kg/d (total)		
Total Particulate (mg)	28	3900	-	11	$Q_s = 1.5 \times 10^3$ kg/d (front end)		
Ag Silver	8.8	6.1	6.4	6	29.3	0.36	4.7
Al Aluminum	130	120	100	100	450	5.9	78
As Arsenic	0.88	1.7	0.84	0.60	3.8	0.05	0.66
B Boron	3100	3600	2200	2.0	7900	100	1400
Be Beryllium	3.1	2.4	2.2	2.0	9.8	0.13	1.7
Cd Cadmium	3.1	2.4	2.2	2.0	10	0.13	1.7
Co Cobalt	31	24	23	20	98	1.3	17
Cu Copper	$\boxed{15}$	12	$\boxed{31}$	10	$\boxed{68}$	$\boxed{0.63}$	$\boxed{8.3}$
Cr Chromium	11	24	$\boxed{30}$	20	$\boxed{110}$	$\boxed{1.4}$	$\boxed{19}$
Fe Iron	$\boxed{480}$	$\boxed{37}$	$\boxed{54}$	$\boxed{20}$	$\boxed{600}$	$\boxed{7.8}$	$\boxed{100}$
Ga Gallium	130	120	96	100	450	5.9	78
Ge Germanium	310	240	220	200	980	13	170
Hg Mercury	44	3.1	3.2	3.0	24	0.18	2.4
In Indium	90	60	60	50	260	1.6	46
Li Lithium	4.4	3.7	3.2	4.0	15	0.20	2.7
Mn Manganese	$\boxed{22}$	6.1	6.4	5.0	$\boxed{40}$	$\boxed{0.52}$	$\boxed{6.8}$
Mo Molybdenum	31	24	22	20	98	1.3	17
Ni Nickel	31	24	42	20	98	1.3	17
Pb Lead	31	24	30	20	107	1.4	19
Sb Antimony	44	49	30	40	170	2.2	29
Sc Scandium	44	37	32	40	150	2.0	26
Se Selenium	1.3	1.2	0.96	1.0	4.5	0.06	0.78
Sn Tin	$\boxed{360}$	120	98	100	$\boxed{580}$	$\boxed{7.6}$	$\boxed{100}$
Sr Strontium	5.7	2.4	2.2	2.0	12	0.17	2.1
Te Tellurium	40	49	30	40	170	2.2	290
Ti Titanium	440	610	130	50	1400	19	150
Tl Thallium	60	17	30	30	140	1.9	25
V Vanadium	3.3	2.4	2.2	2.0	9.8	0.13	1.7
Zn Zinc	$\boxed{75}$	$\boxed{49}$	$\boxed{16}$	$\boxed{26}$	$\boxed{160}$	$\boxed{2.2}$	$\boxed{28}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.1 Summary of Incinerator Stack Source Sampling Tests - Shell-Waterton Plant: Preliminary Survey Glass Liner

Sample Analyses

Test No 1

Date September 3/82

Sample Form	Probe 0.1N HNO3	Imp. 1,2,3,	Microgram Imp. 4,5	Filter	Probe H2O	Maximum Possible Total Elemental Weight µg	Elemental Concentration µg/m³	Elemental Emission Rate g /hr
Volume (ml)	80	780	290	-	420			
Total Particulate (mg)	84	134	-	7.6	84	E_R = 1.7 x 10^3 kg/d (total)		
						E_R = 9.8 x 10^2 kg/d (front end)		
Ag Silver	8.0	6.2	5.0	6.0	13	38	0.67	8.8
Al Aluminum	$\boxed{640}$	160	100	100	130	$\boxed{1100}$	$\boxed{20}$	$\boxed{260}$
As Arsenic	0.08	0.62	0.5	6.0	0.84	8.8	0.16	2.0
B Boron	3200	2300	2000	2000	2900	12800	220	2900
Be Beryllium	2.4	2.3	2.0	2.0	2.9	12	0.21	2.7
Cd Cadmium	3.2	2.3	2.0	2.0	9.7	19	0.34	4.5
Co Cobalt	24	23	20	20	29	120	2.1	27
Cu Copper	$\boxed{110}$	16	$\boxed{20}$	$\boxed{70}$	$\boxed{230}$	$\boxed{446}$	$\boxed{7.9}$	$\boxed{100}$
Cr Chromium	$\boxed{98}$	23	$\boxed{30}$	20	$\boxed{2100}$	$\boxed{2300}$	$\boxed{40}$	$\boxed{530}$
Fe Iron	$\boxed{730}$	$\boxed{480}$	$\boxed{50}$	$\boxed{20}$	$\boxed{12000}$	$\boxed{13000}$	$\boxed{230}$	$\boxed{3000}$
Ga Gallium	160	160	100	100	250	770	14	180
Ge Germanium	320	230	200	200	290	1300	22	290
Hg Mercury	4.0	3.9	2.5	3.0	4.2	18	0.31	4.1
In Indium	80	63	50	50	84	330	5.8	76
Li Lithium	$\boxed{160}$	3.9	2.5	4.0	4.2	$\boxed{160}$	$\boxed{2.8}$	$\boxed{37}$
Mn Manganese	$\boxed{130}$	$\boxed{7.8}$	5.0	5.0	$\boxed{460}$	$\boxed{610}$	$\boxed{11}$	$\boxed{140}$
Mo Molybdenum	8.0	23	20	20	29	100	1.8	23
Ni Nickel	$\boxed{160}$	23	20	20	$\boxed{1800}$	$\boxed{1300}$	$\boxed{23}$	$\boxed{315}$
Pb Lead	$\boxed{41}$	23	7.5	20	29	$\boxed{120}$	$\boxed{2.1}$	$\boxed{28}$
Sb Antimony	48	55	50	40	42	235	4.2	55
Sc Scandium	40	39	$\boxed{80}$	40	42	$\boxed{240}$	$\boxed{4.3}$	$\boxed{56}$
Se Selenium	1.6	1.6	1.0	1.0	1.3	6.4	0.11	1.5
Sn Tin	160	180	100	100	250	770	14	180
Sr Strontium	$\boxed{8}$	2.3	2.0	2.0	2.9	$\boxed{17}$	$\boxed{0.31}$	$\boxed{4.0}$
Te Tellurium	55	55	50	40	42	250	4.4	58
Ti Titanium	160	780	250	50	420	1700	29	380
Tl Thallium	48	39	30	30	42	190	3.4	44
V Vanadium	3.2	2.3	2.0	2.0	2.9	12	0.22	2.9
Zn Zinc	$\boxed{160}$	$\boxed{45}$	$\boxed{21}$	$\boxed{22}$	$\boxed{130}$	$\boxed{380}$	$\boxed{6.8}$	$\boxed{89}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.2 Summary of Incinerator Stack Source Sampling Tests - Shell-Waterton Plant: Test #1 Stainless Steel Liner

Sample Analyses   Test No 2   Date September 6/82   Waterton

Maximum Possible

Sample From	P&W H_2O	IMP. 1,2,3,	Micrograms IMP. 4,5	Filter	Total Elemental Weight μg	Elemental Concentration μg/rcf	Elemental Emission Rate g/hr
Volume (ml)	400	845	275	-	$E_R = 2.0 \times 10^4$ kg/d (total)		
Total Particulate (mg)	37	5900	-	8	$E_R = 1.5 \times 10^2$ kg/d (front end)		
Ag Silver	8.0	5.9	5.5	6.0	25	0.27	3.5
Al Aluminum	120	85	110	100	410	4.3	58
As Arsenic	1.2	0.85	0.6	6.0	8.6	0.09	1.2
B Boron	2800	2500	2200	2000	9500	100	1300
Be Beryllium	2.8	2.5	2.2	2.0	9.5	0.1	1.3
Cd Cadmium	$\boxed{32}$	2.5	2.2	2.0	$\boxed{39}$	$\boxed{0.42}$	$\boxed{5.4}$
Co Cobalt	28	25	22	20	95	1.00	13
Cr Chromium	$\boxed{960}$	$\boxed{36}$	$\boxed{55}$	20	$\boxed{1100}$	$\boxed{11}$	$\boxed{150}$
Cu Copper	$\boxed{160}$	8.5	$\boxed{22}$	$\boxed{10}$	$\boxed{200}$	$\boxed{2.1}$	$\boxed{28}$
Fe Iron	$\boxed{5200}$	$\boxed{160}$	$\boxed{200}$	$\boxed{20}$	$\boxed{5600}$	$\boxed{58}$	$\boxed{770}$
Ga Gallium	120	85	110	100	410	4.3	58
Ge Germanium	280	250	220	200	950	10.0	130
Hg Mercury	4.0	4.2	2.8	3.0	14	0.15	1.9
In Indium	80	59	55	50	240	2.6	34
Li Lithium	4.0	3.4	2.8	4.0	14	0.15	2.0
Mn Manganese	$\boxed{170}$	8.5	5.5	5.0	$\boxed{190}$	$\boxed{2.0}$	$\boxed{26}$
Mo Molybdenum	28	25	22	20	95	1.00	13
Ni Nickel	$\boxed{720}$	25	$\boxed{44}$	20	$\boxed{810}$	$\boxed{8.5}$	$\boxed{110}$
Pb Lead	28	25	$\boxed{14}$	20	$\boxed{88}$	$\boxed{0.92}$	$\boxed{12}$
Sb Antimony	40	51	55	40	190	2.0	26
Sc Scandium	$\boxed{52}$	$\boxed{34}$	$\boxed{28}$	40	$\boxed{150}$	$\boxed{1.6}$	$\boxed{21}$
Se Selenium	1.2	3.4	1.1	1.0	6.7	0.07	0.92
Sn Tin	120	$\boxed{140}$	110	100	$\boxed{470}$	$\boxed{5.0}$	$\boxed{66}$
Sr Strontium	2.8	2.5	2.2	2.0	9.5	0.1	1.3
Te Tellurium	40	51	55	40	190	1.9	26
Ti Titanium	400	850	275	50	1600	16	220
Tl Thallium	40	34	33	30	140	1.4	19
V Vanadium	2.8	2.5	2.2	2.0	9.5	0.1	1.3
Zn Zinc	$\boxed{120}$	$\boxed{79}$	$\boxed{25}$	$\boxed{14}$	$\boxed{240}$	$\boxed{2.3}$	$\boxed{33}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.3 Summary of Incinerator Stack Source Sampling Tests - Shell-Waterton Plant: Test #2 Stainless Stell Liner

Sample Analyses   Test No 3   Date September 7/82   Waterton

Sample From	P[illegible] 0.1N HNO3	Imp. 1,2,3.	Permanganate Imp. 4,5	Filter	Maximum Possible Total Elemental Weight µg	Maximum Possible Elemental Concentration µg/Rm³	Maximum Possible Elemental Emission Rate g/hr
Volume (ml)	*	845	270	-			
Total Particulate (mg)	27	7200	-	7	E_R = 2.3 x 10^4 kg/d (total) E_R = 1.5 x 10^2 kg/d (front end)		
Ag Silver	*	5.9	5.4	5.0	16	0.16	2.1
Al Aluminum	*	85	110	$\boxed{50}$	$\boxed{180}$	$\boxed{1.9}$	$\boxed{25}$
As Arsenic	*	0.85	1.1	0.6	2.6	0.03	0.33
B Boron	*	420	540	400	1400	13	180
Be Beryllium	*	2.5	2.2	1.0	5.7	0.06	0.75
Cd Cadmium	*	2.5	2.2	2.0	6.7	0.07	0.87
Co Cobalt	*	25	22	10	57	0.56	7.4
Cu Copper	*	$\boxed{11}$	$\boxed{11}$	$\boxed{10}$	$\boxed{32}$	$\boxed{0.31}$	$\boxed{4.1}$
Cr Chromium	*	25	22	20	67	0.07	0.87
Fe Iron	*	$\boxed{65}$	$\boxed{180}$	$\boxed{30}$	$\boxed{290}$	$\boxed{2.8}$	$\boxed{38}$
Ga Gallium	*	85	110	100	290	2.9	38
Ge Germanium	*	85	110	100	290	2.9	38
Hg Mercury	*	5.9	5.4	5.0	16	0.16	2.1
In Indium	*	85	110	100	290	2.9	38
Li Lithium	*	2.5	2.2	2.0	6.7	0.07	0.87
Mn Manganese	*	5.9	$\boxed{5.4}$	5.0	$\boxed{16}$	$\boxed{0.16}$	$\boxed{2.1}$
Mo Molybdenum	*	25-	22	20	67	0.66	8.7
Ni Nickel	*	25	22	20	67	0.66	8.7
Pb Lead	*	25	22	20	67	0.66	8.7
Sb Antimony	*	42	54	20	120	1.1	15
Sc Scandium	*	59	54	30	140	1.4	19
Se Selenium	*	0.85	4.1	1.0	3.0	0.03	0.38
Sn Tin	*	25	110	50	180	1.8	24
Sr Strontium	*	8.3	11	10	29	0.29	3.8
Te Tellurium	*	59	54	50	110	1.1	14
Ti Titanium	*	250	220	100	570	56	74
Tl Thallium	*	34	27	30	91	0.89	12
V Vanadium	*	2.5	2.2	1.0	5.7	0.06	0.76
Zn Zinc	*	$\boxed{59}$	$\boxed{27}$	$\boxed{15}$	$\boxed{100}$	$\boxed{1.0}$	$\boxed{13}$

All elements except those in boxes ☐ are below the limit of detection.

* Sample Destroyed

Table VI.4 Summary of Incinerator Stack Source Sampling Tests - Shell-Waterton Plant: Test #3 Stainless Steel Liner

Sample Analyses　　Test No 4　　Date September 9/82　　Maximum Possible

Sample Form	Pan and HNO_3	Imp. 1,2,3.	[illegible] Imp. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/m³	Elemental Emission Rate g/hr
Volume (ml)	470	840	250		R_g = 1.6 x 10^4 kg/d (total)		
Total Particulate (mg)	35	11000	-	-	R_g = 2.5 x 10^2 kg/d (front end)		
Ag Silver	4.7	5.9	5.0	6.0	22	0.4	2.8
Al Aluminum	140	84	100	100	430	4.1	57
As Arsenic	0.94	0.84	0.5	0.6	2.9	0.03	0.39
B Boron	2000	2900	2000	2000	9100	89	1200
Be Beryllium	2.8	2.5	2.0	2.0	9.3	0.09	1.3
Cd Cadmium	2.8	2.5	2.0	2.0	9.3	0.09	1.2
Co Cobalt	28	25	20	20	93	0.89	12
Cu Copper	$\boxed{80.4}$	8.4	$\boxed{10}$	$\boxed{70}$	$\boxed{130}$	$\boxed{1.2}$	$\boxed{17}$
Cr Chromium	$\boxed{40}$	25	$\boxed{30}$	20	$\boxed{120}$	$\boxed{1.1}$	$\boxed{15}$
Fe Iron	$\boxed{460}$	$\boxed{72}$	$\boxed{50}$	$\boxed{20}$	$\boxed{600}$	$\boxed{5.7}$	$\boxed{78}$
Ga Gallium	140	84	100	100	430	4.1	57
Ge Germanium	280	250	200	200	930	8.9	120
Hg Mercury	2.6	4.2	2.5	3.0	12	0.12	1.7
In Indium	47	590	50	50	740	7.0	98
Li Lithium	1.9	8.4	7.5	4.0	22	0.21	2.9
Mn Manganese	4.7	8.4	5.0	5.0	23	0.22	3.07
Mo Molybdenum	28	25	20	20	93	0.89	12
Ni Nickel	28	25	20	20	93	0.89	12
Pb Lead	28	25	20	20	93	0.89	12
Sb Antimony	47	50	50	40	190	1.8	25
Sc Scandium	19	84	$\boxed{75}$	40	$\boxed{220}$	$\boxed{2.1}$	$\boxed{29}$
Se Selenium	1.4	$\boxed{2.2}$	1.0	1.0	$\boxed{5.6}$	$\boxed{0.05}$	$\boxed{0.70}$
Sn Tin	47	340	250	100	730	7.0	98
Sr Strontium	2.8	2.5	2.0	2.0	9.3	0.09	1.3
Te Tellurium	47	50	50	40	190	1.8	25
Ti Titanium	470	840	250	50	1600	15	220
Tl Thallium	42	34	30	30	140	1.3	18
V Vanadium	2.8	2.5	2.0	2.0	9.3	0.09	1.3
Zn Zinc	$\boxed{44}$	$\boxed{54}$	$\boxed{30}$	$\boxed{24}$	$\boxed{150}$	$\boxed{1.5}$	$\boxed{20}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.5　Summary of Incinerator Stack Source Sampling Tests - Shell-Waterton Plant Test #4 Glass Liner

Sample Analyses Test No 5 Date October 6/82

Waterton

Maximum Possible

Sample From	PSW [illegible]	IMP. 1,2,3.	Microgramme IMP. 4,5	Filter	Total Elemental Weight µg	Elemental Concen-tration µg/m³	Elemental Emission Rate g /hr
Volume (ml)	+ 200	780	290	-			
Total Particulate (mg)	5	7700	-	32	$E_R = 2.2 \times 10^4$ kg/d (total) $E_R = 1.0 \times 10^2$ kg/d (front end)		
Ag Silver	10	23	15	5.0	53	0.52	6.2
Al Aluminum	200	390	290	$\boxed{50}$	$\boxed{930}$	$\boxed{9.0}$	$\boxed{110}$
As Arsenic	2.0	3.9	2.9	0.6	9.4	0.09	1.1
B Boron	800	1600	1200	400	3900	18	460
Be Beryllium	4.0	7.8	5.8	1.0	19	0.18	2.2
Cd Cadmium	4.0	7.8	5.8	2.0	20	0.19	2.3
Co Cobalt	40	78	58	10	190	1.8	22
Cu Copper	$\boxed{20}$	39	29	10	$\boxed{98}$	$\boxed{1.1}$	$\boxed{1.2}$
Cr Chromium	40	78	58	20	200	1.9	23
Fe Iron	$\boxed{60}$	$\boxed{78}$	$\boxed{58}$	$\boxed{30}$	$\boxed{210}$	$\boxed{2.0}$	$\boxed{24}$
Ga Gallium	200	390	290	100	980	9.5	120
Ge Germanium	200	390	290	100	980	9.5	120
Hg Mercury	10	29	14	5.0	60	0.67	8.0
In Indium	200	390	290	100	980	9.5	120
Li Lithium	4.0	7.8	5.8	2.0	20	0.19	2.3
Mn Manganese	10	23	15	5.0	53	0.52	6.2
Mo Molybdenum	40	78	58	20	100	1.9	23.
Ni Nickel	40	78	58	20	200	1.9	23
Pb Lead	40	78	58	20	200	1.9	23
Sb Antimony	80	$\boxed{230}$	120	20	$\boxed{450}$	$\boxed{4.4}$	$\boxed{53}$
Sc Scandium	100	240	150	30	520	5.0	61
Se Selenium	2.0	3.9	2.9	1.0	9.8	0.10	1.2
Sn Tin	200	390	290	50	930	9.0	110
Sr Strontium	20	39	29	10	98	0.95	12
Te Tellurium	100	230	150	50	530	51	62
Ti Titanium	400	780	580	100	1900	18	220
Tl Thallium	60	120	87	30	290	2.9	35
V Vanadium	4.0	7.8	5.8	1.0	19	0.18	2.2
Zn Zinc	$\boxed{50}$	$\boxed{70}$	$\boxed{38}$	$\boxed{19}$	$\boxed{180}$	$\boxed{1.7}$	$\boxed{21}$

All elements except those in boxes ☐ are below the limit of detection.

+ part of probe and nozzle wash lost during analysis

Table VI.6 Summary of Incinerator Stack Source Sampling Tests - Shell-Waterton Plant: Test #5 Glass Liner

Sample Analyses	Test No 6		Date October 7/82		Maximum Possible		
Sample From	P&W 6M HNO3	Micrograms IMP. 1,2,3.	IMP. 4,5	Filter	Total Elemental weight µg	Elemental Concentration µg/ref—	Elemental Emission Rate g /hr
Volume (ml)	680	580	360		$E_R = 1.9 \times 10^4$ kg/d (total)		
Total Particulate (mg)	39	6400	-	23	$E_R = 1.8 \times 10^2$ kg/d (front end)		
Ag Silver	6.8	6.2	7.2	5.0	25	0.24	3.1
Al Aluminum	140	88	110	$\boxed{50}$	$\boxed{380}$	$\boxed{3.7}$	$\boxed{46}$
As Arsenic	1.4	$\boxed{2.6}$	1.1	0.6	$\boxed{5.7}$	$\boxed{0.06}$	$\boxed{0.69}$
B Boron	540	530	360	400	1800	18	220
Be Beryllium	2.7	2.6	2.5	1.0	8.8	0.09	1.1
Cd Cadmium	2.7	2.6	2.5	2.0	9.9	0.1	1.2
Co Cobalt	27	26	25	10	89	0.85	11
Cu Copper	$\boxed{27}$	$\boxed{12}$	11	10	$\boxed{60}$	$\boxed{0.6}$	$\boxed{7.3}$
Cr Chromium	27	26	25	20-	99	1.0	12
Fe Iron	$\boxed{340}$	$\boxed{180}$	$\boxed{36}$	$\boxed{50}$	$\boxed{600}$	$\boxed{5.8}$	$\boxed{73}$
Ga Gallium	140	88	110	100	430	4.2	52
Ge Germanium	140	88	110	100	430.	4.2	52
Hg Mercury	6.8	6.2	7.2	5.0	25	4.2	52
In Indium	140	88	110	100	430	4.2	52
Li Lithium	2.7	2.6	2.5	2.0	9.9	0.10	1.2
Mn Manganese	6.8	6.1	7.2	5.0	25	0.24	3.1
Mo Molybdenum	27	26	25	20	99	1.0	12
Ni Nickel	27	26	25	20	99	1.0	12
Pb Lead	27	26	25	20	99	1.0	12
Sb Antimony	54	53	36	20	160	1.6	20
Sc Scandium	68	62	72	30	230	2.2	28
Se Selenium	1.4	0.9	1.1	1.0	4.3	0.04	0.5
Sn Tin	140	$\boxed{530}$	36	50	$\boxed{750}$	$\boxed{7.2}$	$\boxed{91}$
Sr Strontium	14	8.8	11	10	43	0.42	5.3
Te Tellurium	68	62	72	50	250	2.4	31
Ti Titanium	270	$\boxed{530}$	250	100	$\boxed{1200}$	$\boxed{11}$	$\boxed{140}$
Tl Thallium	41	35	36	30	140	1.4	17
V Vanadium	2.7	2.6	2.5	1.0	8.8	0.09	1.1
Zn Zinc	$\boxed{61}$	$\boxed{62}$	$\boxed{36}$	$\boxed{15}$	$\boxed{170}$	$\boxed{1.7}$	$\boxed{21}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.7 Summary of Incinerator Stack Source Sampling Tests - Shell-Waterton Plant: Test #6 Glass Liner

Sample Analyses   Test No 7   Date October 3/82   Waterton

Sample From	P&H [illegible]	IMP. 1,2,3.	IMP. 4,5	Filter	Maximum Possible Total Elemental Weight µg	Elemental Concentration µg/scf	Elemental Emission Rate g /hr
	Micrograms						
Volume (ml)	600	350	175	-			
Total Particulate (mg)	36	7400	-	38	$E_R = 2.2 \times 10^4$ kg/d (total)		
					$E_1 = 2.2 \times 10^2$ kg/d (front end)		
Ag Silver	6.0	6.0	3.0	5.0	21	0.20	2.6
Al Aluminum	120	85	110	$\boxed{100}$	$\boxed{420}$	$\boxed{4}$	$\boxed{52}$
As Arsenic	1.2	0.85	4.1	0.60	6.8	0.07	0.84
B Boron	480	310	410	400	1800	17	220
Be Beryllium	2.4	2.6	2.3	1.0	8.3	0.08	1.0
Cd Cadmium	2.4	2.6	2.3	2.0	9.3	0.09	1.2
Co Cobalt	24	26	23	10	82	0.80	10
Cu Copper	$\boxed{12}$	8.5	20	10	$\boxed{52}$	$\boxed{0.50}$	$\boxed{6.4}$
Cr Chromium	24	26	23	20	92	0.89	11
Fe Iron	$\boxed{180}$	$\boxed{340}$	$\boxed{75}$	$\boxed{50}$	$\boxed{650}$	$\boxed{6.2}$	$\boxed{79}$
Ga Gallium	120	85	110	100	420	4.0	52
Ge Germanium	120	85	110	$\boxed{100}$	$\boxed{420}$	$\boxed{4.0}$	$\boxed{52}$
Hg Mercury	6.0	6.0	3.8	5.0	21	0.20	3.0
In Indium	120	8.5	110	100	340	3.3	42
Li Lithium	2.4	2.6	2.3	2.0	9.3	0.9	1.2
Mn Manganese	6.0	6	3.8	5.0	21	0.20	3.0
Mo Molybdenum	24	26	23	20	92	0.89	10
Ni Nickel	24	26	23	20	92	0.89	10
Pb Lead	24	26	23	20	92	0.89	10
Sb Antimony	$\boxed{48}$	51	38	20	$\boxed{160}$	$\boxed{1.5}$	$\boxed{19}$
Sc Scandium	60	60	38	30	190	1.8	23
Se Selenium	1.2	0.85	1.1	1.0	4.2	0.34	.52
Sn Tin	120	85	110	50	370	3.5	46
Sr Strontium	12	8.5	11	10	42	0.40	5.2
Te Tellurium	60	60	38	50	310	2.0	26
Ti Titanium	240	255	225	100	820	7.9	102
Tl Thallium	36	34	34	30	130	1.3	17
V Vanadium	2.4	2.6	2.3	1.0	8.3	0.08	1.0
Zn Zinc	$\boxed{66}$	$\boxed{43}$	$\boxed{38}$	$\boxed{15}$	$\boxed{160}$	$\boxed{1.5}$	$\boxed{20}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.8 Summary of Incinerator Stack Source Sampling Tests - Shell-Waterton Plant: Test #7 Glass Liner

Sample Analyses   Test No Prelim   Date October 9/82   Maximum Possible

Sample From	Probe and HNO_3	Imp. 1,2,3.	Microgramme Imp. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/m³	Elemental Emission Rate g/hr
Volume (ml)	570	770	310		Q_s = 7.2 x 10^3 kg/h (actual)		
Total Particulate (mg)	29	26000	-	21	Q_s = 2.2 x 10^1 kg/h (Dry std)		
Ag Silver	5.7	6.2	6.2	6.0	24	0.36	0.30
Al Aluminum	$\boxed{170}$	150	93	$\boxed{100}$	$\boxed{520}$	$\boxed{7.7}$	$\boxed{6.5}$
As Arsenic	1.7	1.3	0.93	0.50	4.7	0.07	0.06
B Boron	1700	1500	930	1000	5200	77	63
Be Beryllium	2.9	3.3	2.2	1.0	9.3	0.12	0.10
Cd Cadmium	2.9	3.3	2.2	1.0	9.3	0.14	0.12
Co Cobalt	29	23	22	10	83	1.2	1.04
Cu Copper	$\boxed{200}$	15	9.3	10	$\boxed{230}$	$\boxed{3.5}$	$\boxed{2.9}$
Cr Chromium	5.7	23	22	30	71	1.1	0.88
Fe Iron	$\boxed{110}$	$\boxed{33}$	$\boxed{62}$	$\boxed{30}$	$\boxed{220}$	$\boxed{3.3}$	$\boxed{2.7}$
Ga Gallium	290	330	320	300	930	14	12
Ge Germanium	170	150	93	100	520	7.7	6.3
Hg Mercury	1.7	1.5	0.93	1.0	5.2	0.08	0.07
In Indium	170	150	93	100	530	7.7	6.5
Li Lithium	1.7	1.3	0.93	0.60	4.8	0.07	0.06
Mn Manganese	5.7	6.2	6.2	6.0	24	0.36	0.30
Mo Molybdenum	57	62	62	50	230	3.5	2.9
Ni Nickel	29	62	22	20	130	0.41	0.34
Pb Lead	29	62	22	30	130	2.0	1.7
Sb Antimony	$\boxed{57}$	54	31	20	$\boxed{160}$	$\boxed{2.4}$	$\boxed{2.0}$
Sc Scandium	57	62	62	20	200	3.0	2.5
Se Selenium	1.7	1.54	0.93	1.0	5.18	0.08	0.06
Sn Tin	170	150	93	50	470	7.0	5.9
Sr Strontium	5.7	6.2	6.2	9.0	27	0.40	0.34
Te Tellurium	57	62	62	60	240	3.6	3.0
Ti Titanium	$\boxed{170}$	$\boxed{230}$	93	60	$\boxed{560}$	$\boxed{8.3}$	$\boxed{6.9}$
Tl Thallium	57	62	62	50	230	3.5	2.9
V Vanadium	2.9	15	2.2	3.0	22	0.33	0.28
Zn Zinc	$\boxed{63}$	$\boxed{15}$	$\boxed{43}$	$\boxed{16}$	$\boxed{140}$	$\boxed{2.0}$	$\boxed{1.7}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.9 Summary of Incinerator Stack Source Sampling Tests - Gulf-Pincher Creek: Preliminary Survey Glass Liner

Sample Analyses	Test No 1		Date October 10/81		Pincher Creek Maximum Possible		
Sample Form	[illegible] HNO_3	Imp. 1,2,3,	Microgram Imp. 4,5	Filter	Total Elemental Weight µg	Elemental Concentration µg/m³	Elemental Emission Rate g /hr
Volume (ml)	600	800	183		$Q_s = 1.1 \times 10^4$ [illegible] (total)		
Total Particulate (mg)	20	30000	-	34	$Q_s = 1.6 \times 10^3$ [illegible]		
Ag Silver	6.1	6.3	7.1	6.0	25	0.44	0.36
Al Aluminum	240	$\boxed{360}$	110	$\boxed{100}$	$\boxed{810}$	$\boxed{14}$	$\boxed{11}$
As Arsenic	1.2	0.90	1.1	3.0	6.2	0.14	0.12
B Boron	1200	900	1100	1000	4200	73	59
Be Beryllium	2.4	2.7	2.5	1.0	8.6	0.15	0.12
Cd Cadmium	$\boxed{2.4}$	2.7	2.5	2.0	$\boxed{9.6}$	$\boxed{0.17}$	$\boxed{0.14}$
Co Cobalt	24	27	25	10	86	1.5	1.21
Cu Copper	$\boxed{61}$	9.0	11	10	$\boxed{90}$	$\boxed{1.2}$	$\boxed{1.3}$
Cr Chromium	24	27	25	20	96	1.7	1.4
Fe Iron	$\boxed{240}$	$\boxed{90}$	$\boxed{32}$	$\boxed{20}$	$\boxed{380}$	$\boxed{6.6}$	$\boxed{5.4}$
Ga Gallium	240	270	250	200	960	17	14
Ge Germanium	120	90	110	100	420	7.2	5.9
Hg Mercury	1.2	0.90	3.6	1.0	6.7	0.12	0.09
In Indium	120	90	110	100	420	7.2	5.9
Li Lithium	$\boxed{1.2}$	0.90	1.1	0.6	$\boxed{3.8}$	$\boxed{0.07}$	$\boxed{0.06}$
Mn Manganese	6.1	6.3	7.1	6.0	25	0.44	0.36
Mo Molybdenum	61	63	71	50	240	4.2	3.5
Ni Nickel	24	27	23	20	94	1.7	1.4
Pb Lead	24	27	23	20	94	1.7	1.4
Sb Antimony	48	54	36	20	160	2.7	2.2
Sc Scandium	61	63	71	20	210	3.7	3.0
Se Selenium	1.2	0.90	1.1	1.0	4.2	0.07	0.06
Sn Tin	120	90	110	50	370	6.4	5.2
Sr Strontium	6.1	6.3	7.1	10	29	0.51	0.42
Te Tellurium	61	63	71	60	250	4.4	3.6
Ti Titanium	$\boxed{120}$	$\boxed{360}$	$\boxed{110}$	60	$\boxed{650}$	$\boxed{11}$	$\boxed{9.1}$
Tl Thallium	61	63	71	50	240	4.2	3.5
V Vanadium	2.4	2.7	2.5	2.0	9.6	0.17	0.14
Zn Zinc	-	$\boxed{34}$	$\boxed{11}$	$\boxed{20}$	$\boxed{65}$	$\boxed{1.5}$	$\boxed{1.2}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.10 Summary of Incinerator Stack Source Sampling Tests - Gulf-Pincher Creek: Test #1 Glass Liner

Sample Analyses | Test No 2 | Date October 10/83 | Pincher Creek

Maximum Possible

Sample From	[illegible]	Imp. 1,2,3.	[illegible] Imp. 4,5	Filter	Total Elemental Weight µg	Elemental Concen-tration µg/m³	Elemental Emission Rate g/hr
Volume (ml)	715	940	430		[illegible]		
Total Particulate (mg)	51	-	-	14	[illegible]		
Ag Silver	5.7	5.9	4.3	6.0	22	0.32	0.27
Al Aluminum	$\boxed{140}$	$\boxed{84}$	$\boxed{130}$	$\boxed{100}$	$\boxed{560}$	$\boxed{8.1}$	$\boxed{6.7}$
As Arsenic	1.4	6.7	1.3	0.5	9.9	0.15	0.12
B Boron	1400	840	1300	1000	4600	67	55
Be Beryllium	2.1	2.3	2.2	1.0	7.6	0.11	0.09
Cd Cadmium	2.1	2.5	2.2	2.0	8.8	0.13	0.11
Co Cobalt	21	25	22	10	78	1.1	0.95
Cu Copper	$\boxed{36}$	8.4	13	10	$\boxed{67}$	$\boxed{0.98}$	$\boxed{0.81}$
Cr Chromium	21	25	22	20	88	1.3	1.1
Fe Iron	$\boxed{140}$	$\boxed{59}$	$\boxed{34}$	$\boxed{38}$	$\boxed{270}$	$\boxed{3.9}$	$\boxed{3.2}$
Ga Gallium	210	250	230	200	890	13	11
Ge Germanium	140	84	130	100	460	6.7	5.5
Hg Mercury	1.4	0.84	1.29	1.0	4.5	0.07	0.06
In Indium	140	84	130	100	460	6.7	5.5
Li Lithium	1.4	0.84	1.1	0.8	4.2	0.06	0.05
Mn Manganese	5.7	5.9	4.3	6.0	22	0.32	0.27
Mo Molybdenum	57	59	43	50	210	3.1	2.5
Ni Nickel	21	25	22	20	88	1.3	1.1
Pb Lead	21	25	22	20	88	1.3	1.1
Sb Antimony	50	50	43	20	160	2.4	2.0
Sc Scandium	57	59	43	20	180	2.6	2.2
Se Selenium	1.4	0.84	1.3	1.0	4.5	0.07	0.06
Sn Tin	140	84	130	50	410	5.9	4.9
Sr Strontium	5.7	5.9	4.3	5.0	21	0.31	0.25
Te Tellurium	57	59	43	60	220	3.2	2.7
Ti Titanium	$\boxed{220}$	$\boxed{250}$	$\boxed{130}$	60	$\boxed{660}$	$\boxed{9.6}$	$\boxed{7.9}$
Tl Thallium	57	59	43	50	210	3.1	2.53
V Vanadium	2.1	2.5	2.2	2.0	8.8	0.13	0.11
Zn Zinc	$\boxed{16}$	$\boxed{15}$	$\boxed{13}$	$\boxed{18}$	$\boxed{92}$	$\boxed{1.3}$	$\boxed{1.1}$

All elements except those in boxes ☐ are below the limit of detection.

Table VI.11 Summary of Incinerator Stack Source Sampling Tests - Gulf-Pincher Creek: Test #2 Glass Liner

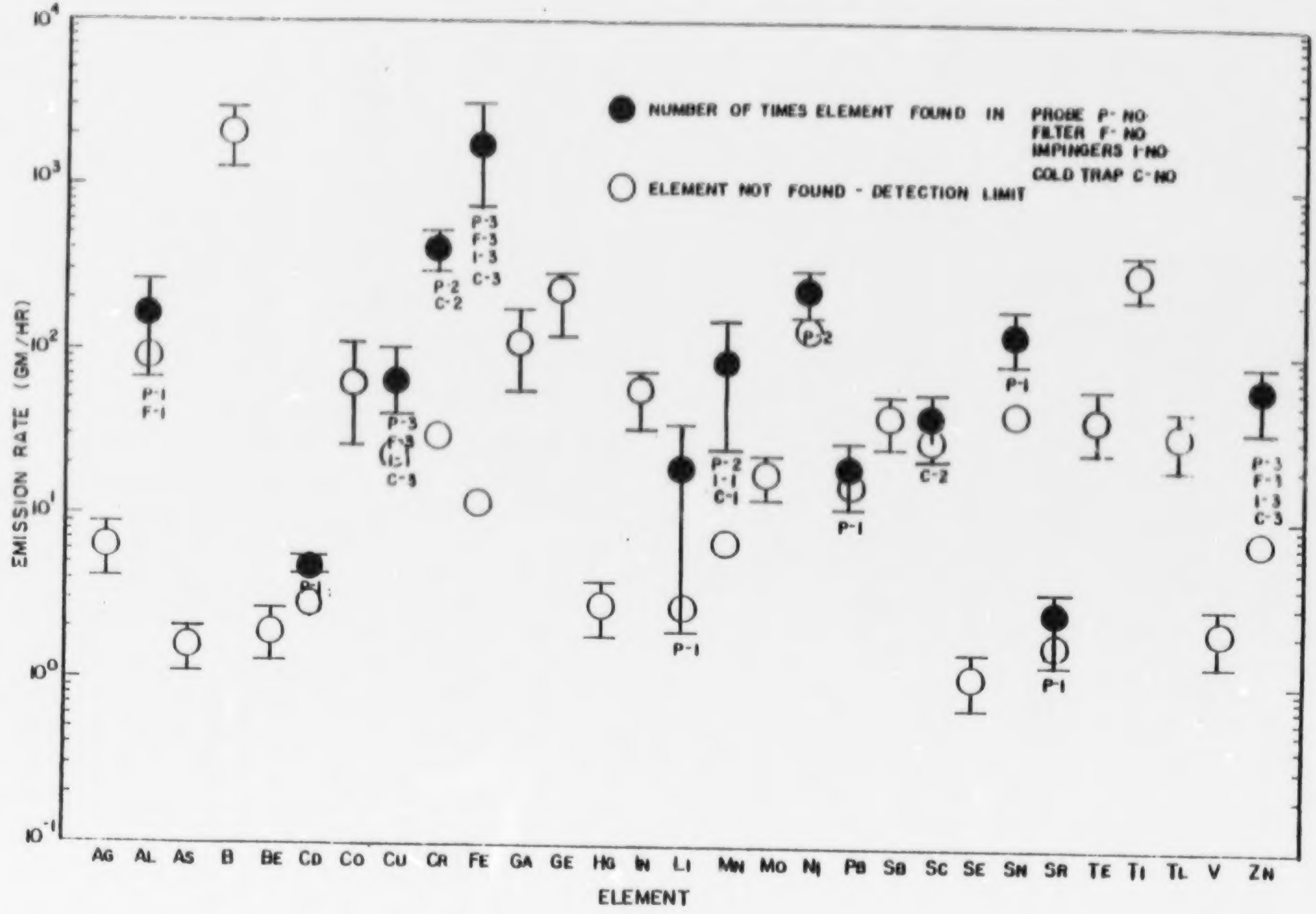


Figure Vl.1 Maximum Possible Emission Rates of All Elements in Shell-Waterton Incinerator Stack Gases (Stainless Steel Liner)

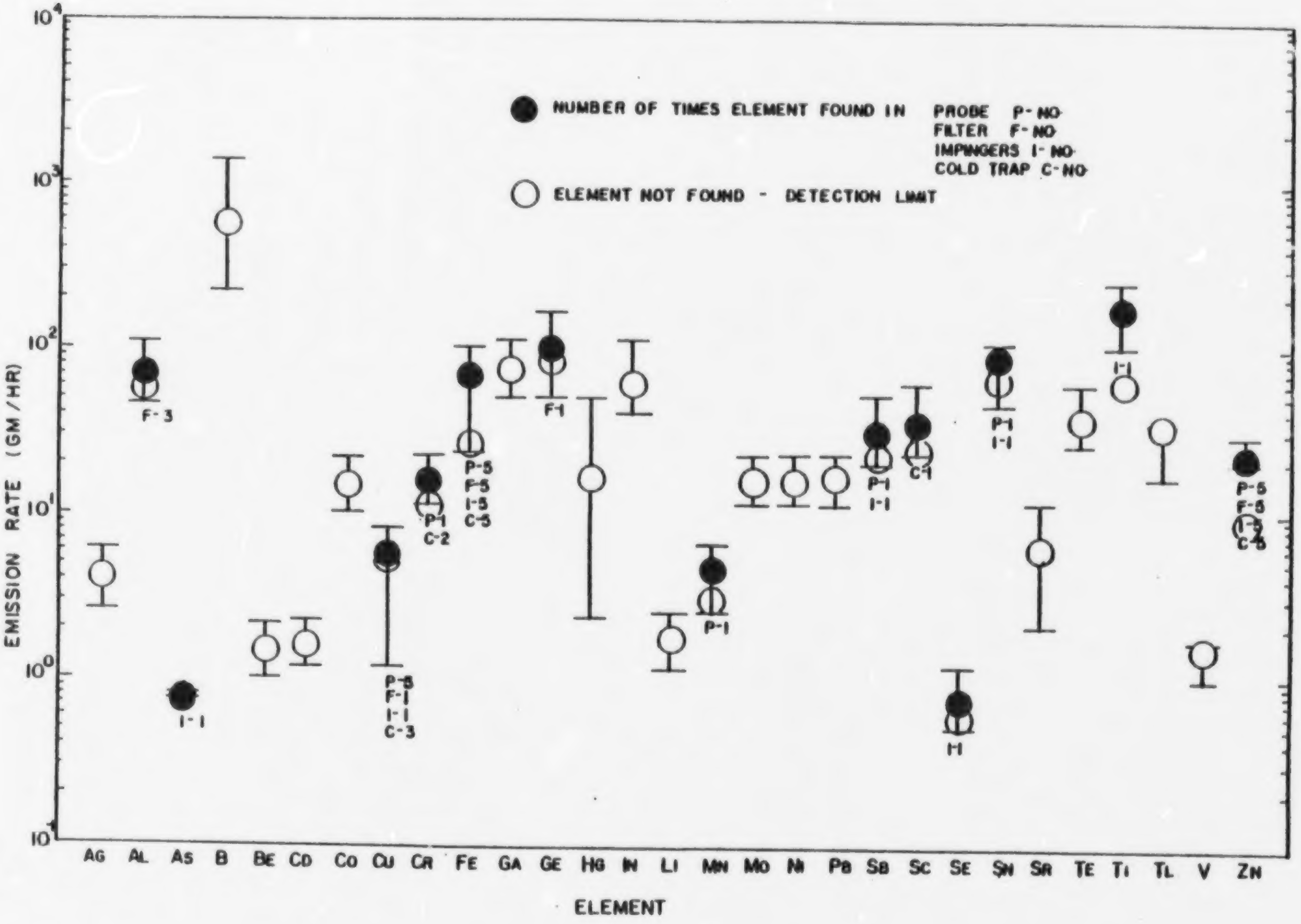


Figure V1.2 Maximum Possible Emission Rates of All Elements in Shell-Waterton Incinerator Stack Gases (Borosilicate Glass Liner)

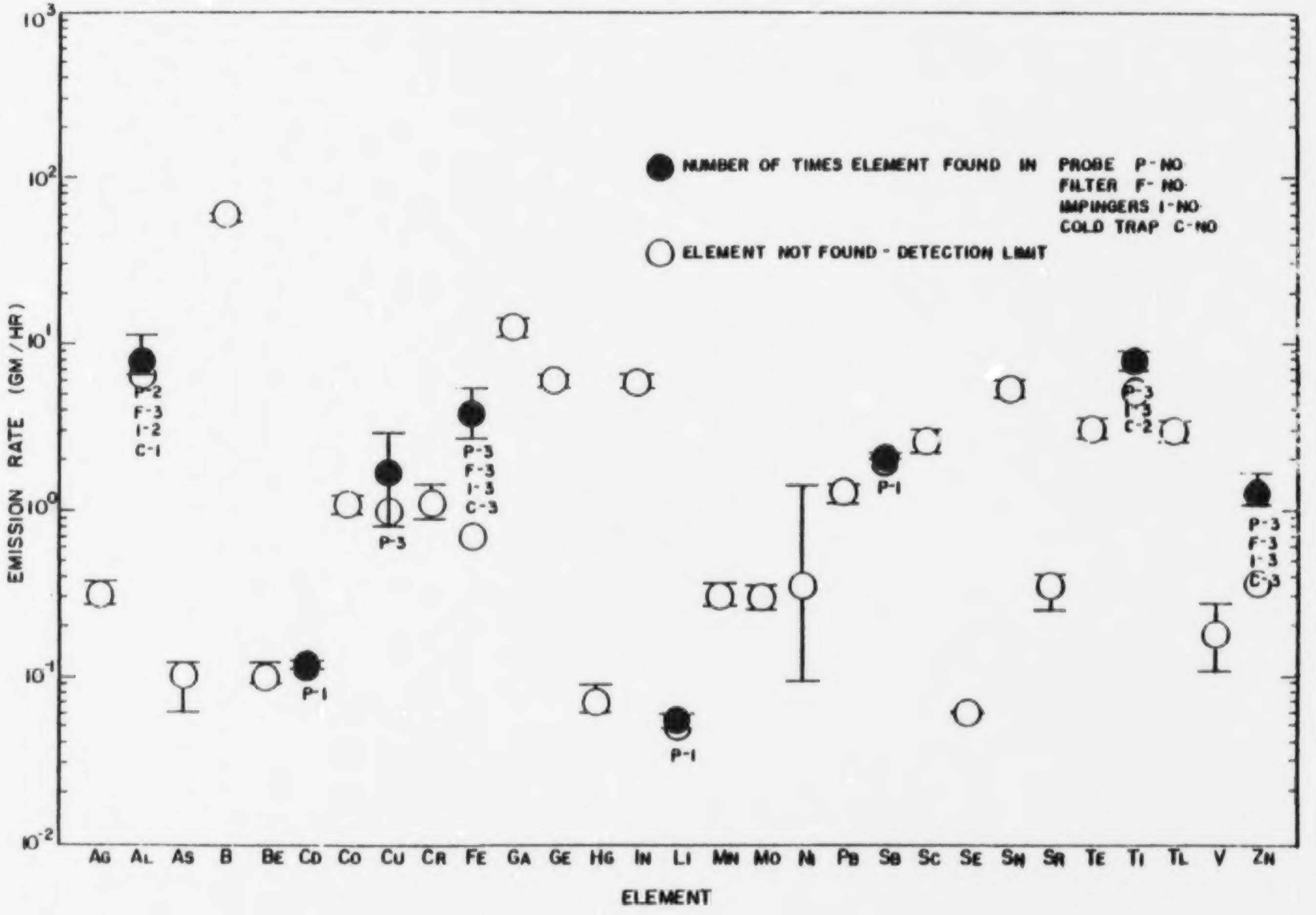


Figure V1.3 Maximum Possible Emission Rates of All Elements in Gulf-Pincher Creek Incinerator Stack Gases (Borosilicate Glass Liner)

		Mass of Arsenic Collected (ug)				Maximum Possible	Arsenic	
Test	Probe and Nozzle (Washes)	Impingers 1, 2, 3	Impingers 4, 5	Filter	Total Sampling Train	Stack Concentration (ug/rcf)	Gas Emission Rate (g/hr)	Comments
Preliminary	0.9	1.7	0.6	0.6	3.8	0.07	0.66	No detection: only LOD levels reported
#4	0.9	0.8	0.5	0.6	2.9	0.03	0.39	No detection: only LOD levels reported
#5	2.0	3.9	2.9	0.6	9.4	0.09	1.10	No detection: only LOD levels reported
#6	1.4	$\boxed{2.6}$	1.1	0.6	$\boxed{5.7}$	$\boxed{0.06}$	$\boxed{0.69}$	Arsenic detected in Impinger 1, 2, 3 solutions: emission rate based on measured and LOD values
#7	1.2	0.9	4.1	0.6	6.8	0.07	0.84	No detection: only LOD levels reported

☐ Element positively detected.

Table V1.12 Summary of Arsenic Determinations at the Shell-Waterton Gas Plant (Borosilicate Glass Liner).

A comparison of the masses of arsenic collected in different parts of the sampling train and resultant evaluations of stack gas concentrations and emission rates for Tests #5 and #6 shows that although the presence of arsenic was never "detected" during Test #5, the respective magnitudes are generally higher than those corresponding to Test #6. Although the Test #6 emission rate (0.69 g/hr) is lower than the 1.10 g/hr value calculated for Test #5, it is reported as exceeding the limit of detection for that test. On the other hand, the Test #5 rate is considered as the maximum value that could be expected if arsenic was present in the stack gases at levels resulting in ultimate solution concentrations equal to the LOD's for instrumental assessment.

Although the presence of arsenic was "detected" in Test #6, neither the number of "detections" nor the concentration at which "detection" was made satisfy the criteria for "establishment" of the presence of arsenic in the Shell-Waterton Gas Plant Incinerator Stack gases. As a result arsenic would not be included in Table 5.6.

The apparent contradiction created by lower emission rates being reported as measured values while higher ones are considered to be hypothetical upper limits can be resolved by reference to Figure VI.4. This schematic illustrates the evaluation of the emission rate of some arbitrary element "X" for which the instrumental limit of detection (LOD) value is assumed to be 1 ug/L.

Steps #1 and #2 involve analysis of aliquots of different volumes of field solutions (A = 400 mL vs. B = 600 mL) which captured element "X" from different volumes of stack gases (100 m^3 vs. 150 m^3). Since the concentrations of both aliquots are below the instrumental limit of detection for element "X", they must be reported as being less than 1 ug/L. On this basis, both samples overestimate the true emission rate considerably.

Concentration of the field liquids (A and B) to 100 mL before analysis according to Steps #3 and #4, provides one solution (C) for which the concentration will be reported as being less than 1 ug/L. The resultant emission rate of 1 ug/s is still an overestimate of the true value. It would be reported as a maximum possible emission rate. However, ultimate solution (D) provides a measurable concentration from which the true emission rate can be evaluated as 0.8 ug/s.

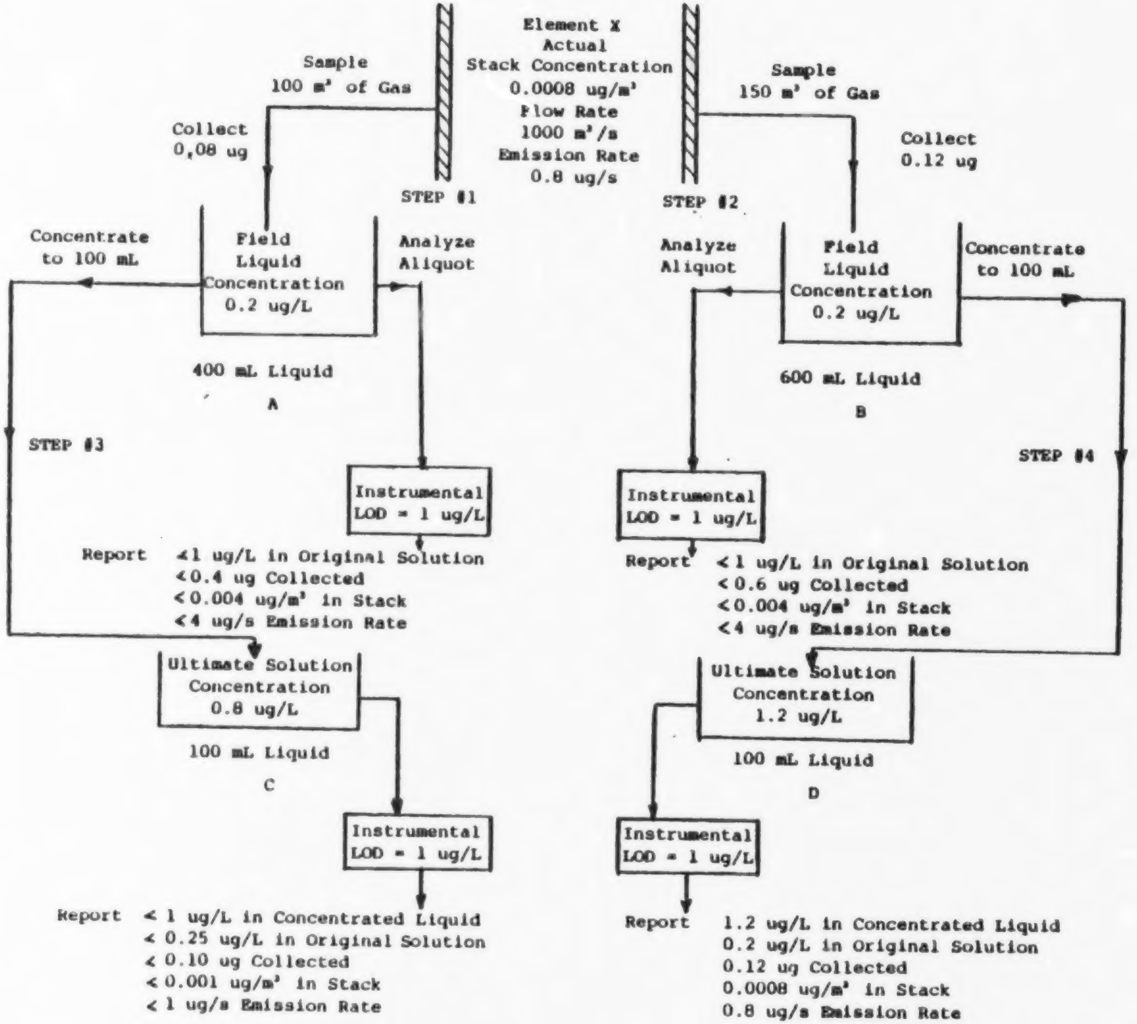

Element X
Actual
Stack Concentration
0.0008 ug/m³
Flow Rate
1000 m³/s
Emission Rate
0.8 ug/s
Sample
100 m³ of Gas
Collect
0,08 ug
STEP #1
Field
Liquid
Concentration
0.2 ug/L
400 mL Liquid
A
Concentrate
to 100 mL
Analyze
Aliquot
STEP #3
Instrumental
LOD = 1 ug/L
Report ≤1 ug/L in Original Solution
<0.4 ug Collected
<0.004 ug/m³ in Stack
<4 ug/s Emission Rate
Ultimate Solution
Concentration
0.8 ug/L
100 mL Liquid
C
Instrumental
LOD = 1 ug/L
Report < 1 ug/L in Concentrated Liquid
< 0.25 ug/L in Original Solution
< 0.10 ug Collected
< 0.001 ug/m³ in Stack
< 1 ug/s Emission Rate
Sample
150 m³ of Gas
Collect
0.12 ug
STEP #2
Field
Liquid
Concentration
0.2 ug/L
600 mL Liquid
B
Analyze
Aliquot
Concentrate
to 100 mL
STEP #4
Instrumental
LOD = 1 ug/L
Report < 1 ug/L in Original Solution
< 0.6 ug Collected
< 0.004 ug/m³ in Stack
< 4 ug/s Emission Rate
Ultimate Solution
Concentration
1.2 ug/L
100 mL Liquid
D
Instrumental
LOD = 1 ug/L
Report 1.2 ug/L in Concentrated Liquid
0.2 ug/L in Original Solution
0.12 ug Collected
0.0008 ug/m³ in Stack
0.8 ug/s Emission Rate

Figure V1.4 Effect of Preconcentration on Reported Emission Rates